TERRESTRIAL MAGNETISM

AND

ATMOSPHERIC ELECTRICITY

(Now entitled Journal of Geophysical Research)

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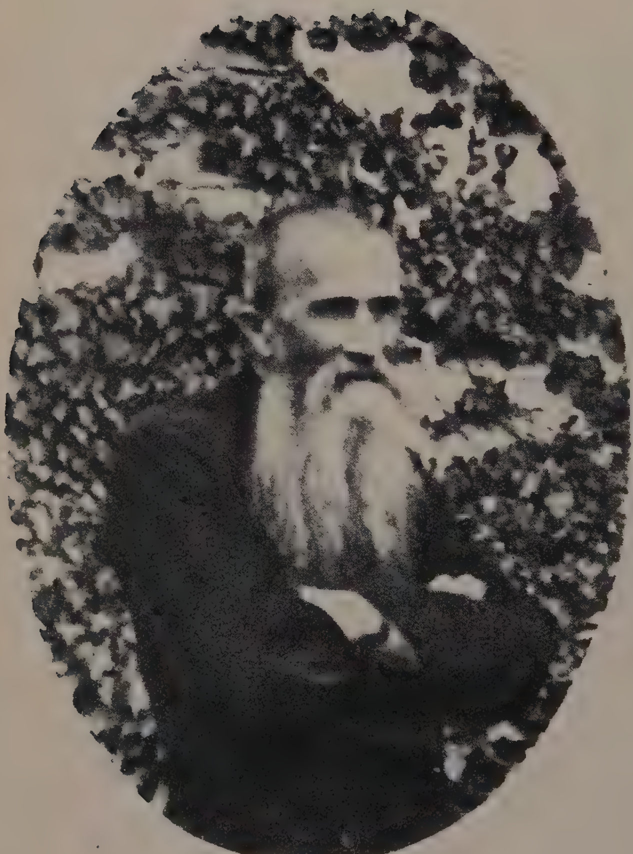

Stanislas Chevalier, S.J.

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 36 MARCH, 1931 No. 1

ON THE CORRELATION OF RADIO RECEPTION WITH THE MOON'S POSITION IN THE OBSERVER'S SKY

BY HARLAN T. STETSON

Papers previously presented by the writer,[1] and by G. W. Pickard[2] and others, have shown significant correlation of the intensity of radio reception with solar activity. The 15-month cycle in secondary maxima, to which particular attention has been called in the present sunspot-cycle by both Stetson and Pickard, have led to numerous speculations as to the possible cosmic causes.

The possibility of planetary influences being the basis for periodic solar disturbances have been exhaustively studied from time to time, notably by Schuster[3], Maunder[4], and Brown[5]. The relatively small tidal forces of the planets give little encouragement for disturbances arising on the gravitational basis. The fact, however, that the 15-month period corresponds fairly closely with two sidereal periods of Venus and five of Mercury, with the arrival of Mercury at perihelion at approximately the same interval, suggested to the writer that charges on these inner planets might be a disturbing factor in the electrostatic equilibrium of the solar atmosphere.

This hypothesis is somewhat further strengthened by the so-called Earth effect on sunspots which has been studied from time to time, particularly by Maunder[4], Stratton[6], Pocock[7], and others. The fact that sunspots tend to subside more readily on the earthward side of the solar surface, and apparently thrive better on the opposite side of the Sun, is suggestive of a truly planetary effect. If the electrical potential of the planets is different from that of the Sun, it would seem reasonable to suppose that electrical charges might even produce a more significant factor than the gravitational forces involved. The assumption that the charge on the planet would be proportional to the charge on the sphere and, therefore, vary as the radius of the planet, would seem to enhance the effects of the inner planets and diminish those of the outer

[1]H. T. Stetson and G. W. Pickard, On the present sunspot maximum and correlation with radio reception, Pop. Astr., **37**, 388-390 (1929).
H. T. Stetson, Influence of sunspots on radio reception, Frank. Inst., **210**, 403-419 (1930); [Perkins Obs. Misc. Sci. Papers, Repr. No. 3].

[2]G. W. Pickard, Correlation of radio reception and solar activity with terrestrial magnetism, Proc. Inst. Radio Eng., **15**, 83-97, 749-766 (1927). Also, Bull. Nation. Res. Coun., No. 61, 133-145 (1927).

[3]A. Schuster, Influence of the planets on the formation of sunspots. Proc. R. Soc., **85**, 309-323 (1911).

[4]A. S. D. Maunder, An apparent influence of the Earth on the numbers and areas of sunspots in the cycle 1889-1901, Mon. Not. R. Astr. Soc., **67**, 451-476 (1907).

[5]E. W. Brown, A possible explanation of the sunspot-period, Mon. Not. R. Astr. Soc., **60**, 599-606 (1900).

[6]F. J. M. Stratton, On the possible phase-relation between the planets and sunspot-phenomena, Mon. Not. R. Astr. Soc., **72**, 9-26 (1911).

[7]R. J. Pocock, The relative numbers and areas of sunspots east and west of the central meridian during the years 1902-1917, Mon. Not. R. Astr. Soc., **79**, 54-58 (1918).

planets. Lacking any direct experimental basis for checking such venturesome theories, a parallel case of the Earth-Moon system presents itself as a problem of worth-while investigation.

If the Moon were a charged body with an electrical potential different from that of the Earth, one would expect that induced charges would occur in the Earth's outer atmosphere which would present a potential gradient along the atmospheric diameter in the direction of the Moon's radius vector. The passage of the Moon about the Earth in its diurnal motion would then give rise to an electronic tide in the Earth's atmosphere. Such an effect, it was thought, would be exhibited through an alternate rise and fall in the Kennelly-Heaviside layer, as a given point on the Earth's surface passes the sub-lunar point and its antipode.

Fortunately, a considerable amount of data is immediately available through the accumulation of measurements of radio intensity, already utilized in the studies of correlation of solar activity with radio phenomena. Accordingly, data gathered from February 1926 to September 1930 by G. W. Pickard, and by the author, have been utilized for the analysis of a possible dependence of radio reception upon the position of the Moon in the sky at the time the records were made. The signal-strengths have been measured with a superheterodyne receiver in connection with automatic recording devices previously described.[1] The intensity measured represents the strength of the carrier-wave in microvolts received in the antenna from the broadcasting station of *WBBM*, Chicago, operating on 770 kilocycles. The measured strengths have been confined for this purpose to those received during the hour from 9 to 10 P. M., Eastern Standard Time. The receiving station from February 1926 to February 1928 was that in Pickard's private laboratory in Newton Centre, Massachusetts. The subsequent data were received at Cambridge, Massachusetts, when the apparatus now in use at the Perkins Observatory was in use at the Harvard Astronomical laboratory.

In making an analysis, the mean signal-strength for the evening, reduced to a common standard, was entered upon a data-card together with the Moon's hour-angle and declination for the mid-time of the observation. The card-catalogue when completed comprised nearly 1600 nights' observations. The cards were then sorted in accordance with the Moon's hour-angle and 24 groups selected from the set, each group representing a range of one hour in the Moon's hour-angle from the meridian. The mean results for the several groups were tabulated. Running means were then taken, taking five nights at a time, giving a series of 24 normal points which, when plotted, exhibit the graph in Figure 1. A study of the curve here presented is distinct evidence for a correlation between the Moon's hour-angle and the strength of the received radio signal. Interpreting the varying signal-strengths as a variation in the height in the Kennelly-Heaviside layer from which the broadcasted wave is refracted, we would interpret an increasing signal-strength as an increase in height in the ionized layer of the Earth's atmosphere. This interpretation is in accordance with that previously used in tracing the behavior of increased solar activity as a contributing cause in diminished signal-strengths. As decreasing solar activity has usually been accompanied during the interval of observation with a rise in signal-strength, we have supposed that a lift in the critical ionization-level has resulted from a decrease in the ionization from solar causes.

Interpreting, therefore, the lunar curve in a similar way, the maximum height of the Kennelly-Heaviside layer would seem to occur when the Moon's hour-angle is between 10 and 14.

If a change in ionization-level is the direct result of an induced charge caused by a charge on the Moon, it appears that the noted effect should become more striking if we transform coordinates from hour-angle and declination into altitude and azimuth and replot the intensity of radio signal-strengths as a function of the Moon's altitude above the horizon at the time of observation. The result of this transformation of coordinates and replotting of the curve is shown in Figure 2.

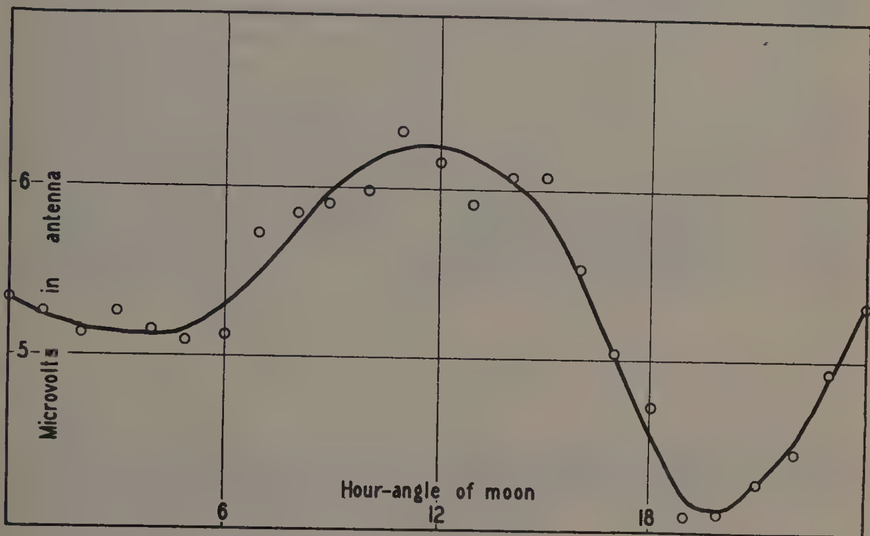

FIG. 1

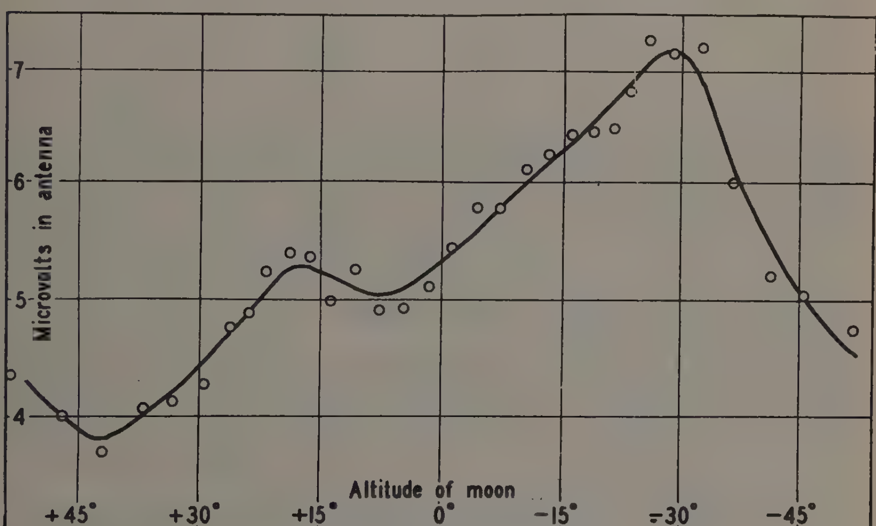

FIG. 2

Interpreting the curve, it will be borne in mind that $(90°-h)$, where h is the altitude in degrees of the moon above the horizon, is effectively the distance of the observer in degrees on the Earth's surface from the sub-lunar point. The striking rise and fall of radio reception with the Moon's changing altitude (Fig. 2) appears to leave little doubt as to the reality of a correlation. Since many hundred nights' observations are involved, well distributed over the curve of solar activity, it is believed that the influence of solar activity in this graph is fairly well eliminated. Furthermore, since the years 1926-1929 inclusive represent, in general, the rather flat top of the present maximum of the 11-year solar cycle, the solar effect, so far as the 11-year term is concerned, has been fairly constant throughout the interval.

It will be noted that a marked ascendency in the radio curve (Fig. 2) occurs when the Moon sets and assumes negative altitudes, and that the maximum signal-strengths were recorded when the Moon was well below the horizon. The effect seems to be precisely what would accompany a rise in the effective height of the Kennelly-Heaviside layer over the observer when the Moon is on the under side of the Earth, and a depression in the Kennelly-Heaviside layer as the Moon nears the point overhead of the observer. It is believed that a reasonable explanation follows on the assumption that the Moon is a negatively charged body.

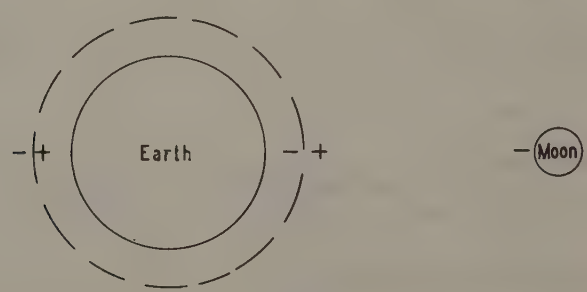

FIG. 3

Reference to the diagram in Figure 3 illustrates the question. The presence of the negatively charged Moon over the point A results in a relatively positive charge (or lessened negative charge) being induced on the outer shell of the Kennelly-Heaviside layer at B and an increased negative charge on the under side of the shell at C. This increase in the negative charge on the inside of the ionized shell effectively lowers the altitude of the Kennelly-Heaviside layer, thereby producing decreased signal-strengths just as an increased negative charge in this layer caused by an electronic bombardment during higher solar activity effectively lowers the affected layer.

As the observer passes to the under side of the Earth, as may be seen in Figure 3, the condition becomes reversed with respect to the observer. The negative charge on the inside of the Kennelly-Heaviside layer is here appreciably lessened by the positive charge induced by the Moon. The reflecting ionized layer over D, therefore, rises in this instance with the accompanying improvement in signal-strengths.

The departure of the form of the curve in Figure 2 from a sine-curve appears consistent with the general map of the electronic field of the

Earth-Moon system shown in Figure 4. The relatively normal directions of the lines of force on the side of the Earth next to the Moon favor a flattening of the equipotential surface in this area, whereas on the opposite side of the Earth, the equipotential surface rises towards a peak. An examination of Figure 2 shows that the radio field appears relatively low between altitude $+40°$ and $0°$, indicating a consistent depression of the Kennelly-Heaviside layer. This is precisely what would be expected from an examination of the equipotential surface on the Moon side of the Earth as depicted in Figure 4. The abruptness of the rise in the intensity of signal-strength in Figure 2, as the Moon's altitude becomes negative and the Moon passes beneath the observer, appears consistent with the rapid rise of the equipotential surface on the side of the Earth away from the Moon.

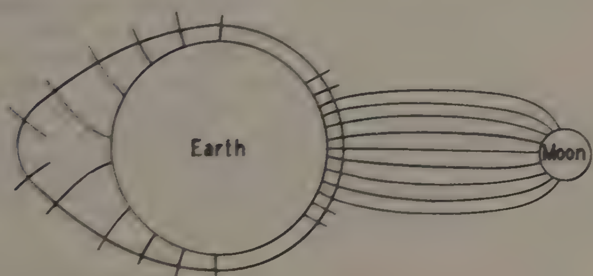

Fig. 4

The fact that the maximum in the curve in Figure 2 occurs when the Moon has a critical altitude of $-30°$, rather than when the Moon attains its maximum altitude for Boston, suggests a lack of symmetry consistent with an appreciable lag in the electronic tide.

If continued observations should substantiate the conclusions here drawn, it would appear that measurements in the varying height of the Kennelly-Heaviside layer, through the persistence of measuring signal-strength, may lead eventually to sufficient data whereby it may be possible to measure effectively the charge upon the Moon with respect to the Earth.

The possibility of entertaining charges on celestial bodies does not appear seriously at variance with any practical deductions from the laws of celestial mechanics, although it would appear possible that such conclusions might lead ultimately to the assignment of slightly different values for the supposed masses of some of the planets, deduced on the supposition of the gravitational theory alone.

Acknowledgment is due the American Academy of Arts and Sciences for a grant from its Rumford Fund for the purchase of apparatus used in obtaining the observations. I am also indebted to G. W. Pickard for supplying some of the earlier radio data from his manuscript files, and to Marvin Cobb, of the Perkins Observatory, for assistance in the computations.

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THE EFFECT OF THE SUNSPOT-CYCLE ON THE MAGNETIC DIURNAL VARIATION AT APIA

By C. J. Westland

Abstract—In this article the data used are the hourly values in magnetic declination, D, and horizontal intensity, H, each hourly value having been computed from the mean ordinate to the curve during the period of sixty minutes commencing at the Greenwich hour stated. The difference between the highest and lowest hourly value in the day is called simply the "Range," brevitatis causâ. Results of harmonic analyses are given following the notation H or $D = m + r_1 \sin (A_1 + t) + r_2 \sin (A_2 + 2t) + \ldots\ldots$

In preparing to make harmonic analyses of the diurnal variations of the magnetic elements at Apia, the first difficulty was to find the most suitable material. We have mean curves derived from the all-day results in the years 1905 to 1929, and it might seem natural to use these values. But the objection to using any such mean curve is that the effect of the sunspot-cycle upon the ranges in magnetic horizontal intensity, H, is so pronounced, that the values of the coefficients must depend upon the number of years of sunspot maximum included in the period contributing to any such mean curve. Obviously there can not be a normal curve in the real sense of the word.

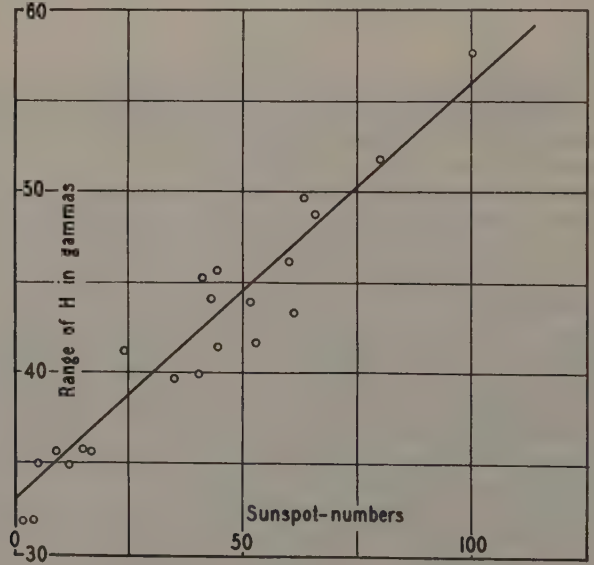

Fig. 1

To show how conspicuous the effect is upon the ranges in H, consider Figure 1. Here the mean ranges expressed in γ during March, April, September, and October in each year from 1905 to 1927 are plotted vertically above the sunspot-numbers taken from left to right. The ranges at the seasons of the solstices give results similar to these shown

at the equinoctial seasons. If we consider Figure 1 to be the graph of $R\gamma = (33 + 0.22S)$, then the result found at the season of the northern solstice, May, June, July, August, is the graph of $(22+0.20S)$, and the remaining four months representing the southern solstice give $(37+0.20S)$.

When the ranges and the sunspot-numbers are treated as problems in correlation, the coefficients are found to be unity or nearly so, showing that this method is not suitable for the purpose for which it has been used.

Under these circumstances it must be seen that the only plan that can give useful results is to compute the harmonic constants at both maximum and minimum periods of solar activity. The means for each month in the years 1917, 1918, and 1919 have been taken for the time of maximum activity, and similar data for 1922, 1923, and 1924 have been used for the time of minimum.

The results in H are shown in Table 1. The coefficients of the first and second terms are respectively 30 and 34 per cent greater at maximum, than those found at minimum.

The problem in magnetic declination, D, is rather more complicated, because there are always two maxima and minima in the diurnal curve. Also there is an annual variation which has the effect that if we were to consider merely the highest and lowest hourly values, we should be contrasting different parts of the curve at different seasons of the year. It is for this reason that I have never tabulated absolute daily maxima and minima in D in the Apia reports—such data would be meaningless and even misleading.

The values in D when examined by graphical methods show no evidence whatever of any sunspot-effect. In order to use them as a problem in correlation, the rule was made that the first maximum in the day and the second minimum were always used for obtaining the range. The coefficients for all three seasons of the year were then

TABLE 1—*Results of harmonic analyses of diurnal variation in magnetic horizontal intensity, Apia, Western Samoa, 1917-19 and 1922-24*

Month	Period maximum solar activity Years 1917, 1918, and 1919								Period minimum solar activity Years 1922, 1923, and 1924							
	r_1	r_2	r_3	r_4	A_1	A_2	A_3	A_4	r_1	r_2	r_3	r_4	A_1	A_2	A_3	A_4
	γ	γ	γ	γ	°	°	°	°	γ	γ	γ	γ	°	°	°	°
Jan.	20.8	11.4	3.7	1.2	107	116	134	118	15.8	9.6	2.9	2.1	103	113	157	220
Feb.	17.4	12.5	4.5	0.9	121	119	144	215	13.5	9.5	4.2	1.2	112	114	128	176
Mar	20.7	12.6	4.1	1.3	116	120	142	176	15.3	8.8	3.0	0.3	100	111	113	150
Apr.	18.6	8.6	2.8	1.2	124	127	137	155	12.2	5.9	1.8	1.5	125	127	136	169
May	16.7	6.7	1.2	1.1	137	143	212	49	9.8	1.8	1.3	1.8	134	139	312	299
June	14.2	5.6	1.5	0.6	131	140	203	123	10.4	4.6	1.1	0.1	135	161	201	300
July	16.5	5.4	1.7	0.6	132	141	170	104	10.7	3.4	1.7	0.6	133	137	137	97
Aug.	22.5	7.2	1.7	1.0	125	146	171	94	12.9	5.3	1.5	1.0	123	150	162	73
Sep.	22.6	7.9	2.9	1.7	123	140	199	20	16.6	6.1	1.8	1.7	127	128	166	172
Oct.	22.6	10.9	4.9	0.5	117	120	152	235	12.9	8.2	2.8	0.3	121	122	135	142
Nov	22.4	12.4	5.1	0.7	109	122	148	215	18.8	12.3	4.3	0.9	105	115	137	288
Dec.	22.1	12.2	4.5	0.4	111	121	150	180	17.4	10.6	5.4	0.9	105	122	137	174

TABLE 2—*Results of harmonic analyses of diurnal variation in magnetic declination, Apia, Western Samoa, 1917-19 and 1922-24*

Month	Period maximum solar activity Years 1917, 1918, and 1919								Period minimum solar activity Years 1922, 1923, and 1924							
	r_1	r_2	r_3	r_4	A_1	A_2	A_3	A_4	r_1	r_2	r_3	r_4	A_1	A_2	A_3	A_4
	′	′	′	′	°	°	°	°	′	′	′	′	°	°	°	°
Jan...	1.17	0.88	0.44	0.13	26	48	97	204	1.22	0.77	0.44	0.09	19	53	105	182
Feb...	1.37	1.00	0.49	0.26	22	52	97	91	1.10	0.78	0.58	0.30	21	36	87	105
Mar..	0.88	1.26	0.66	0.28	4	20	68	87	0.65	0.67	0.49	0.17	13	28	95	133
Apr...	0.40	0.68	0.33	0.10	352	349	36	142	0.52	0.65	0.40	0.10	339	353	38	106
May..	0.23	0.86	0.48	0.21	333	339	9	10	0.22	0.64	0.39	0.08	336	331	8	345
June..	0.17	0.73	0.62	0.19	276	330	351	354	0.28	0.39	0.34	0.17	222	286	339	343
July..	0.21	0.86	0.53	0.23	324	324	349	3	0.28	0.62	0.41	0.18	247	314	342	355
Aug...	0.36	1.14	0.79	0.23	332	332	24	18	0.42	0.64	0 51	0.17	260	320	344	350
Sep...	0.60	0.92	0.60	0.22	331	348	29	36	0.40	0.80	0.42	0.17	336	334	10	2
Oct...	1.07	0.93	0.64	0.17	9	34	76	122	0.62	0.66	0.46	0.24	10	26	75	114
Nov..	1.42	1.03	0.81	0.24	18	53	103	145	1.01	0.91	0.60	0.18	13	51	106	138
Dec...	1.60	1.01	0.68	0.18	20	55	115	294	1.20	1.03	0.62	0.08	14	43	96	212

found to be only between 0.20 and 0.30. Thus it seemed possible that there might be a sunspot-effect, but it still remained doubtful.

Table 2 solves the problem at once. The coefficients of the second term at time of maximum solar activity are 32 per cent greater than those found at time of minimum.

The results in magnetic vertical intensity, Z, are held over for the present, because they have not been found altogether satisfactory. They seem to show that some of the data used have serious faults.

GIANT MICROPULSATIONS AT ABISKO

By Bruno Rolf[1]

At the Geophysical Observatory of Abisko, Swedish Lapland, a set of Toepfer variometers has been in operation since midsummer 1921, with a break of one month only in October to November 1927, when more rigid mountings were made. The time-scale has been 20 mm per hour and sensitivities of 5γ in eastward, 10γ in northward, and 8γ in vertical component per mm most of the time.

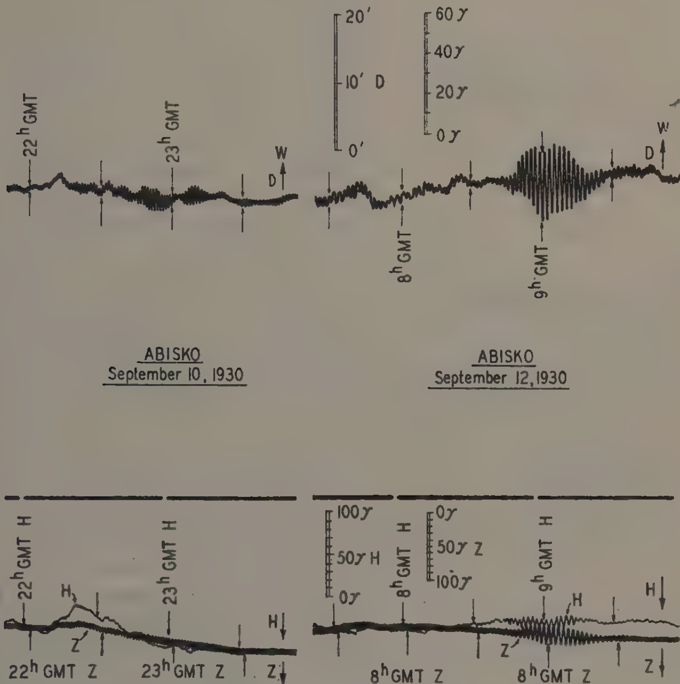

Fig. 1—Giant micropulsations recorded at Abisko, September 10 and 12, 1930

The portions of records reproduced in Figure 1 were obtained on September 10 and 12, 1930, and illustrate a special kind of rare perturbation, which occurs distinctly only three or four times a year at Abisko. Its characteristic feature is a regularly emerging and vanishing sinusoid with period of order of one minute. With more sensitive instruments, somewhat regular pulsations are not uncommon, and their existence is well known to scientists even at lower latitudes. My first acquaintance with similar phenomena dates back to August 1914, when in charge of the temporary magnetic station erected in connection with the solar eclipse at Strömsund, Central Sweden. Professor V. Carlheim-Gyllensköld at once directed my attention to the explanation of Eschenhagen's "Elementarwellen" given by Professor C. Störmer[2] in 1906. The sensitivity in the Strömsund records for all elements was about 1.5γ per mm, and in a fortnight similar micropulsations were conspicuous

[1]First meteorologist, Director of Abisko Geophysical Observatory, Sweden.
[2]Comptes Rendus, 143, 460-464 (1906).

several times with a range of about 1γ. The pulsations of September 12, 1930, at Abisko, however, had ranges of 14γ in the northward component, 34γ in the eastward, and 23γ in the vertical component. True giant amongst dwarfs! There were about 50 full swings with a mean period of 111 seconds, and the phenomenon lasted for 1 hour and 27 minutes.

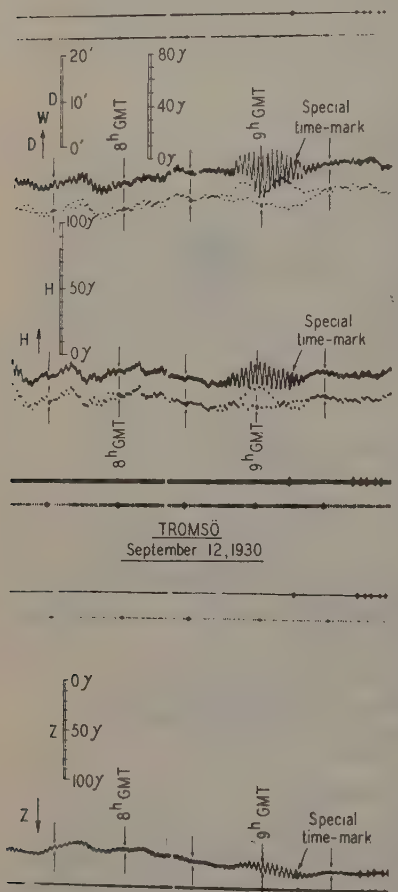

FIG. 2—Giant micropulsations recorded at Tromsö, September 12, 1930

Too little evidence seems to be assembled as to the geographical aspect of these pulsations, which cannot be adequately explained without such knowledge but which seem generally regarded as identical over the whole globe[3]. Observatories are unfortunately seldom equipped with sufficiently sensitive variometers to allow physical disentangling of what really occurs when such micropulsations are recorded. The opportunity offered by the giant micropulsations of September 12 for such a study seems unique. Results bearing upon the theory of the Earth's magnetism as well as on the choice of instruments with open time-scale for the Polar Year might be expected from such study.

I, therefore, wrote to L. Harang of Tromsö Observatory, 149 kilometers due north of Abisko, who earlier had proposed an exchange of interesting magnetograms, and to Dr. Keränen, formerly of Sodankylä Observatory, 347 kilometers east 15° south, asking them for copies of their records of "the giant." I also consulted Dr. Ljungdahl of Lovö Observatory, west of Stockholm. I have the pleasure here to acknowledge my indebtedness to them all. The Tromsö record is particularly interesting, as a special time-mark during the pertubation allows a tolerable determination of the relative phases in the three components to be made—better than I had secured from the Abisko record. In both cases the end of the horizontal perturbing-vector makes a clockwise rotation, on an ellipse, whose major axis is east-northeast to west-southwest and east by southeast to west by northwest, respectively. At both stations the pulsation in the northward component leads: at Tromsö the vertical lags 25° and the eastward component 105° behind the northward one.

[3]Thus G. Angenheister, in the chapter on magnetic disturbances in Das Magnetfeld der Erd (Handbuch der Experimentalphysik, **25**, I, p. 667 (1928)), says: "Pulsationen, einige zusammenhängende sinusförmige Schwingungen von Perioden meist unter 3 Minuten und von einer Intensität, die selten 5γ übersteigt. Sie umfassen gleichzeitig die ganze Erde. . . ."

TABLE 1—*Ranges of the micropulsations at about 9h Greenwich mean time September 12, 1930*[4]

Observatory	Distance	Component		
		N	*E*	*Z*
	km	γ	γ	γ
Abisko	0	14	34	23
Tromsö	149	16	30	10
Sodankylä	347	7	9	6
Kandalakscha	591	<3?	<2	<1?
Naes	631	3.1	2.7	1
Lovö	1,005	<1	<1	<1
Pavlovsk	1,119	<1	<1	<1
Rude Skov	1,432	1?	1	<1
Seddin	1,819	0	0	0
De Bilt	1,954	0	0	0
Godhavn	2,742	0	0	0

Lovö, on the contrary, shows no record of simultaneous pulsations. The "giant" thus seems to represent another class of pertubation than those studied heretofore. To settle this point, information would be much appreciated from other observatories whether similar pulsations were recorded on September 12 at 9^h G.M.T. (details or copies of the records may be sent the author addressed to Meteorological Bureau, Stockholm 8, Sweden).

Meanwhile, an examination of all Abisko records from the beginning of recording there in 1921 to November 14, 1930, has revealed the following occurrences of sustained micropulsations, the "range" or double-amplitude of which amounted to at least 6γ in at least one component. Table 2 summarizes the data obtained from this examination.

The first two columns give the year, month, date, and Greenwich time for the central or maximum phase of the phenomenon. The next four columns give the maximum range or double-amplitude in gammas for the components northward (N), eastward (E), vertical (Z), and $(N^2+E^2)^{1/2}$. (As the different components are probably never in phase with each other, $(N^2+E^2)^{1/2}$ has at present no known physical meaning but has been added as possibly a better measure of the horizontal perturbation than N or E separately.) Three columns give approximate duration in minutes, number of certainly discernible full swings, and the period in seconds calculated from duration and number of waves. (No account has been taken of the fact that in some cases the period has been found about 5 per cent greater in the central third of the pulsations than in the first and in the last.) In the last three columns but one the ratios of N and Z to E and of Z to $(N^2+E^2)^{1/2}$ have been given. The last column indicates the classification of each perturbance to one of three groups, namely, "early," "normal," or "late," according to time

[4]Since this paper was prepared further observations, not mentioned in the text, have been received and added to Table 1. For these sincere thanks are due to Prof. Dr. A. Nippoldt of Potsdam, Dr. D. la Cour of Copenhagen, Dr. G. Van Dijk of De Bilt, Dr. W. Popov of Leningrad, and Dr. and Mrs. K. Molin, in charge of the temporary observatory at Naes (latitude 62° 58′ north, longitude 14° 35′ east). Dr. la Cour also courteously procured information by radio from the Godhavn Observatory and kindly examined the Rude Skov records for those days given in Table 2; in only a few cases feeble pulsations were found corresponding to the data in Table 2, which strongly supports the inference that all the pulsations listed are local in character. In connection with this matter, it is interesting to note from a recent letter written the author by Professor Nippoldt that micropulsations at Potsdam "went to sleep" in 1903 and have since been very rare there.

of occurrence before 2^h, between 2^h and 4^h, and after 4^h Greenwich time, respectively.

During these nine years and three months, 28 occurrences were noted. Of these none was in August, November, or December, one was in June and in July, respectively, two were in February and in March, three were in January, April, and May, six were in September, and seven were in October. Thus 13 out of 28 occurred in September and October, which seem the "months of predilection" for this phenomenon. None occurred between 12^h and 21^h G.M.T., four occurred between 21^h and 24^h, three occurred between 0^h and 2^h, 12 occurred between 2^h and 4^h, two occurred between 4^h and 6^h, four occurred between 6^h and 8^h, and three occurred between 8^h and noon. The "hours of predilection" are thus 2^h to 4^h in the morning; it is in consequence of this that we have called the 12 pulsations arriving then "normal," the seven between 21^h and 2^h "early," and the remaining nine "late." The mean data for each of these groups are given at the bottom of Table 2.

Curiously enough, the "normal" pulsations are relatively most infrequent in the "months of predilection" (September and October) and only three out of 13 cases then falling between 2^h and 4^h, the "predilected hours." Of the remaining, seven were "late," that is, arrived after 4^h. In the months of January to April there were four "earlies," five "normal," and one "late"; May to July showed four "normal" against one "late." Objection may be made against such use of the statistics because the more affected by ordinary perturbations a month or an hour is, the greater is the chance for a micropulsation to escape notice, or the bigger must its amplitude be in order to be distinguished among the irregular movements of the traces. I agree that the maximum at 3^h might be enhanced by the fact that the calmest hour is about 4^h to 5^h, but, as the most violent perturbations at Abisko center rather symmetrically around 20^h, the difference in occurrence during the six hours preceding and the six hours following 20^h must be explained in another way. And the yearly period of ordinary perturbations is such as to rather obliterate the autumnal maximum of large micropulsations than to accentuate it.

Admittedly, our data are too scanty to warrant definite statistical results, that is, results which will hold also for a much longer series of records. However, they do suggest certain points which may be with caution temporarily accepted as a guide for tentative explanations: (1) The phenomenon is most frequent in September and October; (2) it is generally most common between 2^h and 4^h G.M.T. except for September and October; (3) the period is generally shorter when the pulsations arrive before 2^h and longer when they arrive after 4^h except for one case in March; (4) the ratio of N to E may assume any value between zero and at least 1.91, but in the mean is about as 2 to 3, with a mean deviation of $+0.42$; (5) the ratio of Z to $(N^2+E^2)^{1/2}$, on the contrary, is always less than unity with deviations from the means less than for that of N to E, and in all months represented is least in the "normal" group, where its value is as 1 to 4, with a mean deviation of $+0.10$, as against 2 to 5 with a mean deviation of $+0.22$ in both the "early" and the "late" groups.

Point (5) together with the absence of perturbation at middle latitudes strongly suggests that the immediate cause of the phenomenon of

TABLE 2—*Catalog of large micropulsations recorded at Abisko from 1921 to 1930*

ate		Gr. mean time	Maximum ranges N	E	Z	$\sqrt{N^2+E^2}$	Duration	Number of swings	Period	Ratios N/E	Z/E	$\frac{Z}{\sqrt{N^2+E^2}}$	Group
		h	γ	γ	γ	γ	min		sec				
ep	8	3.7	16	23	7	28	43	32	81	0.70	0.30	0.25	Normal
ct	5	2.7	1	8	2	8	102	79	77	0.12	0.25	0.25	Normal
an	5	3.3	14	17	6	22	114	63	108	0.82	0.35	0.27	Normal
Mar	6	23.5	1	13	9	13	144	74	117	0.08	0.69	0.69	Early
May	5	2.5	4	7	2	8	45	32	84	0.57	0.29	0.25	Normal
May	14	2.3	*21*	11	3	24	45	28	96	*1.91*	0.27	0.13	Normal
May	15	2.6	6	8	1	10	74	68	65	0.75	*0.12*	0.10	Normal
ct	12	21.1	7	20	5	21	78	76	62	0.35	0.25	0.24	Early
pr	7	7.0	5	6	4	8	106	72	88	0.83	0.67	0.51	Late
pr	9	2.4	3	8	3	9	85	70	73	0.38	0.38	0.35	Normal
pr	9	23.1	*0*	8	2	8	*24*	28	*51*	*0.00*	0.25	0.25	Early
ct	26	3.4	8	10	3	13	58	37	94	0.80	0.30	0.23	Normal
eb	2	1.3	16	15	10	22	165	*109*	91	1.07	0.67	0.46	Early
Mar	3	3.7	3	12	6	12	52	35	89	0.25	0.50	0.50	Normal
an	22	0.6	3	6	2	7	69	43	96	0.50	0.33	0.30	Early
t	27	9.2	4	7	1	8	49	23	128	0.57	0.14	0.12	Late
eb	16	3.1	6	*5*	2	8	157	49	*192*	1.20	0.40	0.26	Normal
ep	25	0.6	8	17	7	19	90	69	78	0.47	0.41	0.37	Early
t	4	5.5	9	18	7	20	70	42	100	0.50	0.39	0.35	Late
t	19	7.3	9	22	9	24	88	50	106	0.41	0.41	0.38	Late
l	19	3.4	8	10	3	13	96	53	109	0.80	0.30	0.23	Normal
p	30	4.4	1	11	3	11	29	*19*	91	0.09	0.27	0.27	Late
n	16	7.8	9	7	3	11	*182*	93	117	1.29	0.43	0.26	Late
p	24	11.8	9	7	*1*	11	82	38	129	1.29	0.14	*0.09*	Late
t	23	6.2	2	10	8	10	136	88	93	0.20	0.80	0.78	Late
n	26	3.7	9	14	6	17	93	61	93	0.64	0.43	0.36	Normal
p	10	22.9	6	11	10	13	129	101	77	0.55	*0.91*	*0.80*	Early
p	12	9.1	14	*34*	*23*	*37*	87	47	111	0.41	0.68	0.62	Late
......		3.6	7.2	12.3	5.3	14.8	89	56	96	0.63	0.40	0.35	....
rlies"		23.6	5.9	12.9	6.4	14.6	100	71	82	0.43	0.50	0.44	....
rmals"		3.1	8.2	11.1	3.7	14.2	80	51	97	0.75	0.32	0.26	....
tes"		7.6	6.9	13.6	6.6	15.6	92	52	107	0.62	0.44	0.38	....
eviations													
arlies"........									±22	±0.35	±0.26	±0.22	....
ormals"........									±33	±0.47	±0.10	±0.10	....
ates"........									±15	±0.43	±0.24	±0.23	....

September 12, 1930, is to be sought in currents in the atmosphere above northern Scandinavia. If the soil at Abisko and Tromsö had identical electrical conductivity, one might immediately assert that this cause was more nearly overhead at Tromsö than at Abisko, as the vertical perturbation at the former place was only 45 per cent of that at the latter.

For these two stations one must bear in mind that Tromsö is situated close to the ocean, which has high conductivity, while Abisko is in a uniform region with very low conductivity. To use the difference in effective soil-conductivity at the two places as deduced from the behavior of the daily period of vertical force is not permissible, as in this case the depth of penetration is 30 times greater than in the case of micropulsations with a period of 100 seconds, and thus quite different strata of the Earth's crust come into play in the two phenomena. In the ocean, the currents induced by the micropulsations are practically confined to the upper two kilometers, which thus shield the layers beneath; under the rocks, on the contrary, one has to take account of at least a depth of 30 km.

It would be highly interesting to study such data as those given in Table 2 for other sites than Abisko, and it is hoped that at least some observatories will undertake the compilation from their own records, or examine their records on the days given in Table 2. Thus it may soon be made clear whether two different kinds of "Elementarwellen" do exist, and whether those listed at Abisko do belong to one single class. Possibly the latter may be explained by Störmer's electrified "flying-clouds" if in this case they get much nearer to the Earth and probably have to enter its atmosphere.

[In compliance with the author's request, the Editor prepared the following partial list of references for interested readers:

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Meteorological Bureau,
Stockholm, Sweden,
November 16, 1930

THE GEOGRAPHICAL DISTRIBUTION OF MAGNETIC DISTURBANCE

By W. F. Wallis

Abstract—A discussion at the Department of Terrestrial Magnetism of the magnetic results obtained by the two MacMillan arctic expeditions of 1921-22 and 1923-24, and a comparison of these results with those from several other stations, indicate that during magnetic storms the greatest disturbance occurs in the region of the zone of maximum auroral frequency, and that there is a close correlation between the curves of magnetic activity and auroral frequency when both are plotted in relation to magnetic latitude. A study of the propagation of different types of magnetic disturbance indicates that all types are not propagated with the same velocity. Possible causes of terrestrial magnetic disturbances are discussed.

In a former paper[1] a discussion of the records of the magnetic storm of March 14, 1922, as obtained at several observatories distributed over the Earth, indicated that during magnetic disturbances there is a relationship between the intensity of disturbance at different magnetic latitudes and the corresponding auroral frequency. The zone of maximum auroral frequency appeared to be also a zone of maximum magnetic activity. Passing southward from this zone there was, in the neighborhood of latitude 60°, a sharp drop in the curves of auroral frequency and magnetic activity to a comparatively low level in temperate and equatorial regions.

In the present discussion a different magnetic storm was selected, that of January 29, 1924, and disturbance-data for this storm were compiled and compared for the following eleven observatories: Refuge Harbor (the base-station of the MacMillan Arctic Expedition of 1923-24), Sodankylä, Sitka, Cheltenham, Tucson, Vieques, Honolulu, Antipolo, Huancayo, Vassouras, and Watheroo.

As a basis for the comparison of intensity of disturbance at the different stations use has been made, as in the former case, of the excess energy per cubic centimeter of the magnetic field due to the disturbance as expressed by the equation

$$\triangle E = [X_0\triangle X + Y_0\triangle Y + Z_0\triangle Z]/4\pi + [(\triangle X)^2 + (\triangle Y)^2 + (\triangle Z)^2]/8\pi$$

and also of

$$\triangle R = [(\triangle X)^2 + (\triangle Y)^2 + (\triangle Z)^2]^{1/2}$$

which represents the change in space of the total-intensity vector. The normal values, X_0, Y_0, Z_0, are those derived from the means of the five international quiet days of the month, and are based on average values for an hour centering upon the half-hour. Hourly mean departures from normal during the disturbance are represented by $\triangle X$, $\triangle Y$, and $\triangle Z$. The values of $\triangle E$ and $\triangle R$ were computed for each of the 26 hours of the disturbance. The results are given in Tables 1 and 2, and are shown graphically in Figure 1. The curves indicate much greater activity at the polar stations. On examining the $\triangle E$-curves we find that the peak occurring between 18^h and 19^h is reproduced more or less at almost all the stations. It is positive at five and negative at five stations. At Vassouras it does not appear at all. At Huancayo it appears an hour earlier. A second peak, occurring between 2^h and 3^h, is reproduced at eight of the eleven stations, but at five of these it comes an hour earlier, and is positive at only two stations and negative at six. Sodankylä and Sitka show the greatest effect from the disturbance and Vassouras the least.

In the $\triangle R$-curves also the prominent features of one station show a strong tendency to reproduce themselves at the other stations. Maxima and minima, however, do not occur simultaneously at all the stations. For example, the strong maximum at Refuge Harbor is seen to occur as a maximum at the same time only at Sitka and Watheroo. At Huancayo

[1]Terr. Mag., 35, 93-101 (1930).

HOURLY MEAN VALUES OF ΔE AND ΔR
MAGNETIC STORM OF JANUARY 29, 1924

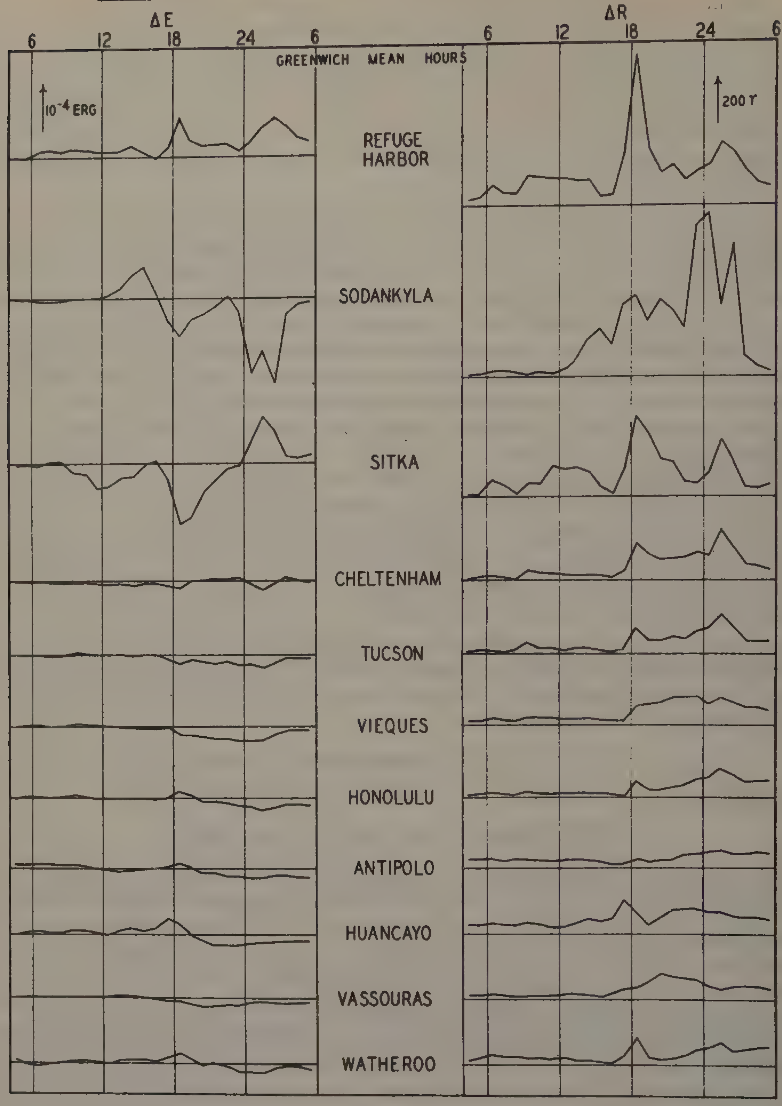

Fig. 1

it appears an hour earlier. The secondary maximum at Refuge Harbor between 1^h and 2^h appears as a principal maximum at Cheltenham, Honolulu, Tucson, Vieques, and Antipolo. In the case of $\triangle R$, Sodankylä shows the greatest effect from the disturbance and Antipolo the least.

In Table 3 the departures from normal of various elements have been summarized by taking numerical means of the hourly mean values for the 26 hours of the storm. The stations are arranged in the order of magnetic latitude. In Table 3 it is seen again that the great preponderance of magnetic activity is in the polar regions, the maximum effect showing at Sodankylä, the station nearest the zone of maximum auroral frequency. After passing magnetic latitude 60° there is a sharp drop to a comparatively low level in temperate and equatorial latitudes, with slight rises at Vieques and Huancayo.

Table 1—*Hourly mean values*[a] *of ΔE for storm-period of 26 hours, 4^h G.M.T. January 29 to 6^h G.M.T. January 30, 1924*

Gr. Mean time	Refuge Harbor	Sodankylä	Sitka	Cheltenham	Tucson	Vieques	Honolulu	Antipolo	Huancayo	Vassouras	Watheroo
h — h											
4— 5	+ 1.3	− 1.6	− 2.8	− 0.6	− 0.8	− 0.3	− 0.6	+ 8.4	+ 0.8	− 2.1	+ 4.7
5— 6	− 1.1	− 1.2	− 2.5	0	+ 0.3	+ 2.9	+ 1.7	+10.7	+ 4.4	− 0.7	− 1.8
6— 7	+ 9.6	− 4.3	− 3.9	− 1.4	+ 0.3	+ 2.7	+ 2.1	+11.5	+ 5.9	+ 0.9	− 6.4
7— 8	+13.7	− 4.8	+ 1.9	− 2.9	− 2.2	− 0.5	− 0.3	+ 8.4	+ 3.5	+ 0.1	− 3.5
8— 9	+10.1	− 3.3	+ 3.0	− 1.8	− 1.2	+ 1.2	− 0.1	+ 7.4	+ 4.1	+ 0.5	+ 0.7
9—10	+16.8	− 0.5	−19.0	− 2.5	+ 4.9	+ 4.8	+ 4.5	+ 6.6	+ 8.5	+ 1.4	+ 2.6
10—11	+13.7	+ 1.4	−23.7	− 2.5	+ 1.7	+ 4.4	+ 0.8	+ 5.2	+ 7.0	+ 1.0	+ 3.8
11—12	+10.2	+ 1.4	−53.0	− 4.6	+ 0.7	+ 3.0	− 3.0	− 0.9	+ 2.2	+ 0.7	+ 1.3
12—13	+10.0	+ 6.7	−49.5	− 7.3	− 0.4	+ 0.1	− 3.3	− 6.0	− 1.2	+ 0.8	+ 1.0
13—14	+12.5	+21.4	−32.7	− 6.3	+ 1.5	− 1.1	− 2.7	− 7.2	+ 6.8	+ 3.0	+ 3.8
14—15	+21.4	+51.0	−29.5	− 9.3	− 0.9	− 4.7	− 2.7	− 5.8	+12.0	+ 1.7	+ 4.9
15—16	+ 8.3	+68.3	− 3.8	− 5.3	+ 0.4	− 4.7	− 2.3	− 3.0	+ 7.5	+ 0.2	+ 5.1
16—17	− 3.5	+14.5	+ 5.0	− 4.8	+ 0.4	− 6.5	− 2.6	+ 1.1	+12.3	− 2.2	+ 1.6
17—18	+17.8	−45.6	−35.1	− 9.2	− 5.7	− 3.1	− 1.3	+ 3.6	+33.3	− 7.7	+12.6
18—19	+84.5	−81.6	−128.3	−15.9	−18.5	−18.6	+13.0	+10.9	+19.6	− 8.8	+19.9
19—20	+34.8	−46.5	−114.1	− 1.0	− 9.7	−20.0	+ 5.3	+ 2.7	− 0.4	−14.8	+ 8.2
20—21	+22.2	−33.4	−59.0	+ 1.7	−14.2	−23.1	− 6.7	− 8.1	−13.9	−20.3	− 5.1
21—22	+25.5	−18.1	−33.7	+ 3.9	−17.0	−27.8	− 8.1	− 8.5	−22.1	−18.1	− 0.5
22—23	+27.4	+ 6.5	−13.9	+ 2.7	−13.5	−27.1	−10.8	−16.2	−23.2	−16.5	− 7.4
23—24	+10.0	−26.3	− 6.5	+ 5.0	−20.6	−29.9	−17.2	−16.4	−23.6	−15.5	−19.4
0— 1	+29.8	−160.8	+43.7	− 4.7	−20.4	−30.7	−19.4	−18.5	−20.3	−10.5	−19.9
1— 2	+60.7	−109.6	+99.3	−19.5	−26.4	−29.8	−26.9	−18.5	−17.8	− 8.1	−21.1
2— 3	+79.7	−178.3	+67.9	− 4.1	−14.7	−18.2	−20.8	−12.7	−15.1	− 9.7	− 9.7
3— 4	+65.9	−34.5	+12.0	+ 5.4	− 4.6	− 8.5	−13.1	−15.0	−14.9	−10.6	− 4.8
4— 5	+41.6	−13.2	+ 6.7	+ 0.8	− 5.4	− 9.0	−13.6	−17.6	−14.4	−10.0	− 7.1
5— 6	+31.8	− 7.8	+16.3	− 2.2	− 6.0	− 7.0	−14.6	−17.6	−12.6	− 7.7	−14.4

[a]In units of a millionth of an erg.

If we plot the numerical mean values of $\triangle E$ and $\triangle R$ according to magnetic latitude for the two storms of March 14, 1922, and of January 29, 1924, the resemblance between the curves of the two storms as plotted in Figure 2 indicates that in a general way the disturbance-effects are distributed over the Earth in very much the same way in both cases. The dotted line indicates auroral frequency as taken from Fritz's curves. However, we see also, for example, in the $\triangle E$-curves of Sitka, Cheltenham, and Vieques, that there are appreciable differences between the two storms, and that at Cheltenham and Vieques, for instance, the differences are not of the same sign. The reason for this is not clear; we find no correlation of these differences with latitude, longitude, position of the Sun, or anything else.

In Table 1, if we compute algebraic instead of numerical means of the columns we find that the average excess energy produced by the storm is positive for the stations within the auroral zone but negative for all the other stations, as shown by Table 4 which includes also similarly computed values for the storm of March 14, 1922. This indicates that the net effect of a storm is an increase in the magnetic flux-density within the auroral zone and a decrease without. From Tables 3 and 4 we may infer that at the auroral zone occurs the maximum disturbance-effect taken in absolute value, while within the auroral zone positive values of energy changes predominate and without the zone negative values.

We may get some idea as to the comparative magnitudes of the two disturbances by taking the sums of the hourly mean values of the $\triangle E$'s or of the $\triangle R$'s for the durations of the storms (Table 5). The ratios $\Sigma(\triangle E)_2/\Sigma(\triangle E)_1$ and $\Sigma(\triangle R)_2/\Sigma(\triangle R)_1$ of the second storm to the first are also shown for each station. Considering $\triangle E$, it is seen that at all

Table 2—*Hourly mean values of* ΔR *for storm-period of 26 hours,* 4^h *G.M.T. January 29 to* 6^h *G. M. T. January 30, 1924*

Gr. Mean time	Refuge Harbor	Sodankylä	Sitka	Cheltenham	Tucson	Vieques	Honolulu	Antipolo	Huancayo	Vassouras	Watheroo
h h	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
4— 5	23	7	9	6	5	10	5	33	33	15	14
5— 6	37	10	10	13	9	14	11	35	33	13	27
6— 7	87	23	80	16	9	21	14	37	40	16	42
7— 8	59	25	49	8	5	14	7	29	35	15	32
8— 9	55	19	10	6	12	14	7	36	35	10	36
9—10	132	9	57	40	42	29	25	36	44	9	28
10—11	121	18	52	29	19	29	13	30	38	10	28
11—12	117	13	128	25	20	24	10	29	27	13	26
12—13	116	28	117	20	13	23	12	35	27	14	31
13—14	105	64	118	20	24	25	13	37	41	23	18
14—15	109	154	103	21	24	22	16	32	60	16	16
15—16	40	200	41	17	13	20	12	24	52	12	12
16—17	46	36	13	12	8	19	9	16	65	21	8
17—18	219	303	113	37	18	18	6	18	143	43	37
18—19	633	344	337	153	110	78	69	38	87	49	112
19—20	237	236	265	104	58	81	36	27	33	80	34
20—21	137	329	153	84	54	92	28	37	71	108	25
21—22	175	288	141	92	73	111	38	38	101	96	31
22—23	110	212	61	95	64	110	49	60	104	87	43
23—24	143	638	51	114	98	117	73	62	105	82	64
0— 1	173	688	99	101	108	86	84	70	94	56	75
1— 2	265	296	241	205	167	117	118	76	92	44	96
2— 3	225	556	148	129	114	98	96	64	76	53	60
3— 4	149	89	37	63	55	77	64	66	70	57	69
4— 5	94	44	36	54	56	71	64	67	68	54	75
5— 6	80	26	51	46	56	61	68	64	60	42	78

stations except Cheltenham the second storm exceeded the first in magnitude, and that in the average the second storm was greater by about 66 per cent. For $\triangle R$ the ratios show a better agreement and give a mean value 1.59. The international magnetic character-number corresponding to the day of the first storm is 1.9, and for the second storm 2.0. The provisional Wolfer sunspot-number assigned to the first day was 53, a high number, and there was a long series of high numbers on the preceding days culminating in the number 127 twelve days before. The number assigned to the day of the second storm was 0, and there was a long series of zeros both before and after that day (January 6 to February 24). So it is evident that sunspots had nothing to do with the second storm. The sunspot minimum came in the year 1923. The first storm came in the year preceding and the second storm in the year following.

Aside from sudden commencements of magnetic storms there are almost no prominent features that persist completely around the Earth. An outstanding peak, or a sharp depression, found on a magnetogram, almost invariably fades out before it gets half-way around the Earth. However, in examining the magnetograms of twelve years, 1913 to 1924, there was found one short sharp disturbance that could be definitely traced entirely around the Earth. This was the disturbance shown in Figure 3 as a sharp wedge-shaped depression in the horizontal-intensity curves near the beginning of the magnetic storm of May 13-17, 1921. The Figure shows also the sudden commencement of the storm at $13^h\ 10^m$, Greenwich mean time. In Table 6 are shown, for ten magnetic observatories, the times of the sudden commencement and of the minimum point, as well as the approximate amount of decrease in horizontal intensity, *H*, measured from the beginning of the sharp descent.

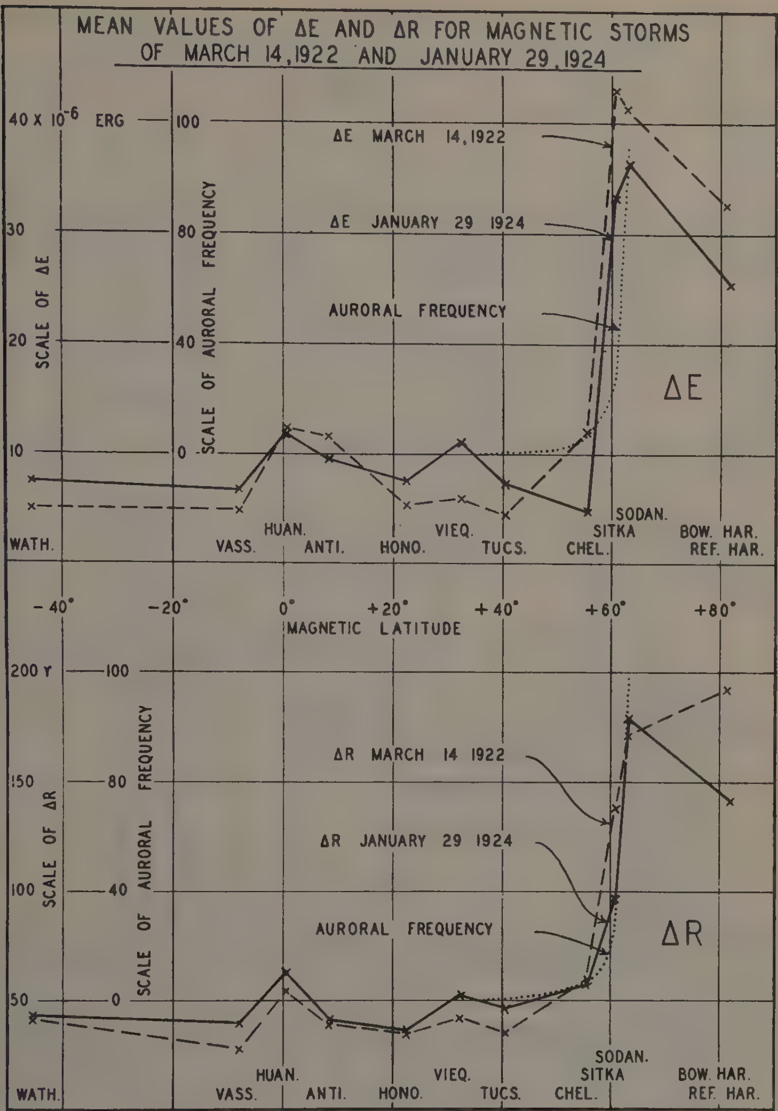

FIG. 2

The times of sudden commencement May 13, 1921, agree within three minutes, which may possibly be the limit of accuracy in the time-measurement of the records and copies used, as it is generally agreed that a sudden commencement is practically simultaneous over the Earth. The times of the minimum point, however, show a progression westward at such a rate that this particular movement would encircle the Earth in about 20 minutes. Assuming that the source of the disturbance was in the Sun, one would naturally suppose that the earliest effect would appear at the *noon* meridian, but in this case it seems to have been at the *midnight* meridian. The values of $\triangle H$ vary roughly as the magnetic latitude. No definite progressive movement in the north-south direction can be detected for this storm of May 1921.

In Figure 3 it may be noticed that at Honolulu this disturbance almost fades out and undergoes considerable modification. Of the two low points occurring at $15^h\ 09^m$ and $15^h\ 22^m$, the first one is probably the same as the

TABLE 3—*Summary of mean departures from normal for storm-period of 26 hours* (4^h *G.M.T. January 29 to* 6^h *G.M.T. January 30, 1924*

Observatory	Mag'c lat.	Lat. north	Long. east	Numerical mean departures from normal							
				ΔD	ΔH	ΔX	ΔY	ΔZ	ΔF	ΔR	ΔE[a]
	°	°	°	′	γ	γ	γ	γ	γ	γ	
Refuge Harbor.....	81.6	78.5	287.6	67	49	76	79	57	59	142	25.5
Sodankylä.........	63.0	67.4	26.6	13	170	135	45	72	100	179	36.3
Sitka..............	60.8	57.0	224.7	6	51	46	40	65	74	97	33.3
Cheltenham........	55.4	38.7	283.2	5	41	41	30	16	10	58	4.8
Tucson............	40.4	32.2	249.2	3	38	37	20	9	17	47	7.4
Vieques...........	32.2	18.2	294.6	2	44	45	17	14	30	53	11.1
Honolulu..........	22.4	21.3	201.9	1	33	33	11	4	25	36	7.6
Antipolo..........	8.2	14.6	121.2	1	33	33	10	20	30	42	9.6
Huancayo.........	0.7	−12.0	284.7	1	50	51	9	30	50	63	11.8
Vassouras.........	− 8.0	−22.4	316.4	1	35	35	10	4	33	40	6.7
Watheroo..........	−45.7	−30.3	115.9	2	33	33	18	11	16	43	7.4

[a]In units of a millionth of an erg.

TABLE 4—*Algebraic mean values of* ΔE *for the storms of March 14, 1922, and January 29, 1924*

Observatory	ΔE[a]	
	Mar. 14, 1922	Jan. 29, 1924
Refuge Harbor..............	......	+25.2
Bowdoin Harbor............	+22.9	......
Sodankylä.................	−19.4	−23.1
Sitka......................	−42.1	−13.7
Cheltenham................	− 9.4	− 3.3
Tucson....................	− 4.1	− 6.6
Vieques...................	− 5.8	− 9.7
Honolulu..................	− 5.3	− 5.5
Antipolo..................	−11.4	− 3.7
Huancayo.................	− 7.0	− 2.0
Vassouras.................	− 4.9	− 5.9
Watheroo..................	− 0.5	− 2.0

[a]In units of a millionth of an erg.

TABLE 5—*Comparison of the magnetic storms of March 14, 1922, and January 29-30, 1924*

Station	$\Sigma(\Delta E)$[a]			$\Sigma(\Delta R)$		
	1922	1924	Ratio 1924/1922	1922	1924	Ratio 1924/1922
				γ	γ	
Sodankylä...........	744	943	1.27	3102	4655	1.50
Sitka................	773	867	1.12	2464	2520	1.02
Cheltenham..........	217	125	0.58	1075	1510	1.40
Tucson..............	87	192	2.20	645	1234	1.91
Vieques.............	107	290	2.71	775	1381	1.78
Honolulu............	96	197	2.05	631	947	1.50
Antipolo............	210	248	1.18	708	1096	1.55
Huancayo...........	222	307	1.38	990	1634	1.65
Vassouras...........	89	174	1.96	500	1038	2.08
Watheroo............	88	191	2.17	758	1117	1.47
Mean...........	263	353	1.66	1165	1713	1.59
Magnetic char. of day.	1.9	2.0	....	....	....	....
Sunspot-number......	53	0	....	....	....	....

[a] In units of a millionth of an erg.

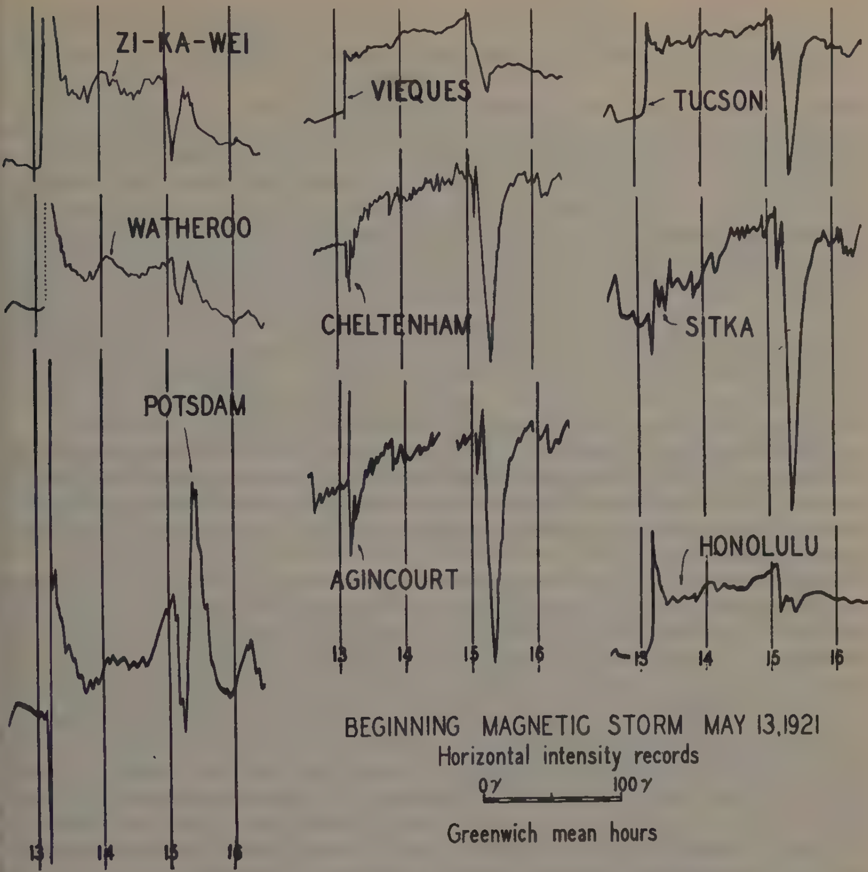

FIG. 3

TABLE 6—*Greenwich mean times of sudden commencement and of minimum point and approximate values of* ΔH *at the minimum point for the magnetic storm of May 13-17, 1921*

Observatory	Latitude	Longitude	Sudden commencement	Minimum point	ΔH
	°	°	h m	h m	γ
Zi-ka-wei	31.2 N	121.4 E	13 07	15 07	−75
Watheroo	30.3 S	115.9 E	13 08	15 10	−37
Potsdam	52.3 N	13.0 E	13 10	15 12	−149
De Bilt	52.1 N	5.2 E	13 10	15 14	−107
Vieques	18.2 N	65.4 W	13 07	15 19	−58
Cheltenham	38.7 N	76.8 W	13 09	15 19	−143
Agincourt	43.8 N	79.3 W	13 07	15 19	−195
Tucson	32.2 N	110.8 W	13 08	15 20	−116
Sitka	57.0 N	135.3 W	13 10	15 20	−206
Honolulu	21.3 N	158.1 W	13 08	15 22	−34

first downward movement after 15^h as recorded at Agincourt, Tucson, and Sitka, while the second one corresponds probably to the minimum point of the other curves.

This storm of May 1921 was one of the two greatest magnetic storms that occurred between 1908 and 1928. It continued for five days and during that time there were four impulses of the sudden-commencement type each one of which was simultaneous over the entire Earth.

From all that precedes it is evident that the geographical distribution of magnetic disturbance is a very complicated matter, and the explanation of the observed facts is exceedingly difficult. According to the latest theories to account for terrestrial magnetic disturbances, for example, the theories of Chapman, Lindemann, Hulburt, and Maris, the causes are to be found in the formation of electric currents in the upper atmosphere by the action of streams of electrified particles propelled from the Sun, or by the ionizing effects of ultraviolet light upon the gases of the upper atmosphere. Hulburt and Maris place these currents at a height between 1,000 and 2,000 kilometers above the Earth's surface. Chapman places them much higher, a distance of a few Earth's radii. But wherever they may be, these primary currents with their rapid fluctuations probably induce secondary currents within the Earth, and possibly also in the Kennelly-Heaviside layer. The combined effects of the primary and secondary currents would undoubtedly be highly complicated changes in the magnetic field at the Earth's surface.

The Kennelly-Heaviside layer, according to the measurements of Hafstad and Tuve,[2] lies at about 200 to 250 kilometers above the Earth's surface. They have shown also that the layer rises during magnetic storms, corresponding to the observed decrease in horizontal intensity at such times.

Another way of explaining the irregular distribution of disturbance over the Earth's surface is to make use of Maris and Hulburt's conception of ion-clouds,[3] employed by them to explain diurnal magnetic-storm variations. These clouds, composed of positive and negative ions produced by blasts of ultraviolet light, are assumed to concentrate at the auroral zones and to act upon the Earth's magnetic field like an immense overhanging bar-magnet. Perhaps we may go farther and assume that there are detached ion-clouds floating around the Earth at lower latitudes which, through changes in level, or changes in form or state, of ionization produce the very irregular changes in the magnetic field that we observe. Hulburt[4] in discussing the origin of the aurora speaks of the ion-layer as probably not uniform but as a thing of shreds and patches.

Another way of looking at these disturbance-phenomena, suggested by the views of Maris and Hulburt,[3] is to regard the Earth as surrounded by a sea of ionized gases, extending from the bottom of the Kennelly-Heaviside layer to 40,000 or 50,000 kilometers above the Earth. In this sea there are always currents flowing mainly in one direction, as shown by Maris and Hulburt in reference cited before, but subject to gentle fluctuations which perhaps cause the diurnal variations. At times of disturbance we may imagine that extraordinary currents are set up, as well as whirls and vortices analogous to meteorological cyclones and anticyclones and to sunspots. Just as each sunspot is accompanied by its own magnetic field, sometimes directed positively towards the Earth and sometimes negatively, it is quite reasonable to suppose that the whirls and vortices of the ionized atmosphere create subsidiary magnetic fields, which, as they float over the Earth at great speed, produce different effects at different places on the Earth according to whether the whirlpool is directly overhead or off at an angle. This would explain such irregular differences as those noticed in the $\triangle E$-curves of Figure 2, and it is conceivable that such a disturbance as that shown in Figure 3 may be caused by the passage of an ionized cyclone.

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[2] Terr. Mag., 34, 39-44 (1929).

[3] Phys. Rev., 33, 412-431 (1929).

[4] Phys. Rev., 31, 1038-1039 (1928).

ON THE DIURNAL VARIATION OF THE AURORA POLARIS*

By E. O. Hulburt

Abstract—The auroral observations of the International Arctic Expedition of 1882-83, of the *Maud* Expedition, of three Antarctic expeditions and of temperate latitudes are assembled in order to bring out the diurnal variation of the aurora forms. Vegard's conclusion that the intense, moving and strongly colored forms are more frequent in the evening than in the morning, the diffuse, weak and quiet forms being more abundant in the morning, appears to be valid. His conclusion that most auroral forms show an evening and a morning maximum is found to be contradicted almost as often as it is upheld. His conclusion that the hour of most frequent auroral occurrence falls near magnetic midnight is not found to be true at the Antarctic stations. On the whole the data give the impression that the diurnal course of an auroral display is different for the different stations, as if it depended upon the meteorology of the upper atmosphere of the station.

Probably the most complete summaries of the facts of the aurora polaris are those of Chree[1] and of Vegard[2]. In dealing with the variation of the aurora during the hours of the day and night Chree concluded that the occurrence of the aurora was usually more frequent in the evening than in the morning, and that arcs, bands, and generally speaking, the more regular and persistent forms show their greatest frequencies earlier in the night than rays or patches of luminosity. Vegard concluded (*a*) that most auroral forms show an evening and a morning maximum and (*b*) that the intense, moving, and strongly colored forms are more frequent in the evening than in the morning, the diffuse, weak, and quiet forms being more abundant in the morning.

It is seen that the conclusions are not in entire agreement, although they were based on much the same sets of observations, mainly those of arctic latitudes. The present paper is the result of an attempt to assemble the data obtained in various latitudes north and south. The conclusion is reached that the diurnal variation of the auroral forms is complex, being different at different stations, and that no completely general statement can be made, although Vegard's conclusion (*b*) appears to be a fair statement of the facts for a number of stations.

The auroral observations are given in Figures 1 to 14, the frequency of the occurrence of the auroral form or type being plotted as ordinate against the hour of the day, local time, as abscissa, 24^h being midnight. In all the curves the maximum ordinates have been made equal and the other values adjusted accordingly. The description printed with each figure gives the name of the station, the year and the distance in degrees of the station from the north or south magnetic pole. Thus 35°N in Figure 1 means that Bossekop is about 35° from the north magnetic pole, and 5°S in Figure 13 means that Cape Adare is about 5° from the south magnetic pole. It will be remembered that the frequency of the occurrence of the aurora is a maximum in a zone about 20° to 30° from the magnetic pole, north or south, and therefore the distance of the station from the magnetic pole may be of interest.

Sverdrup[3] has described the classification of the auroral forms somewhat as follows: *Glows*—large or small patches of aurora with indistinct

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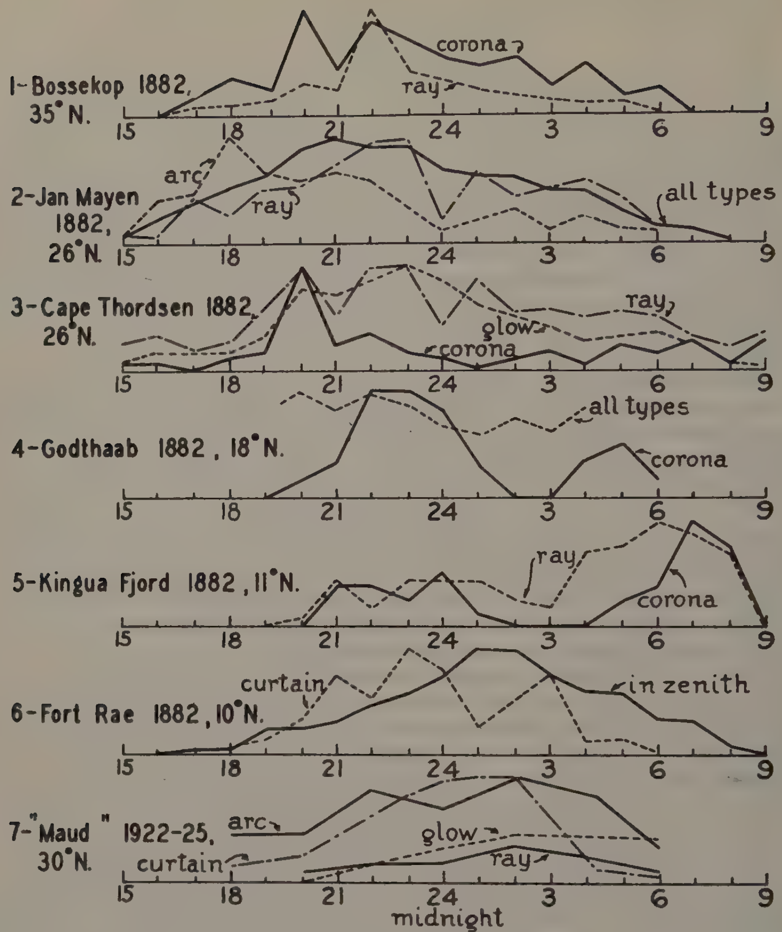
[1]Encyclopaedia Britannica, 13th ed., 2, 927-934 (1926).

[2]Handbuch der Experimentalphysik, 25, I, 385-476 (1928).

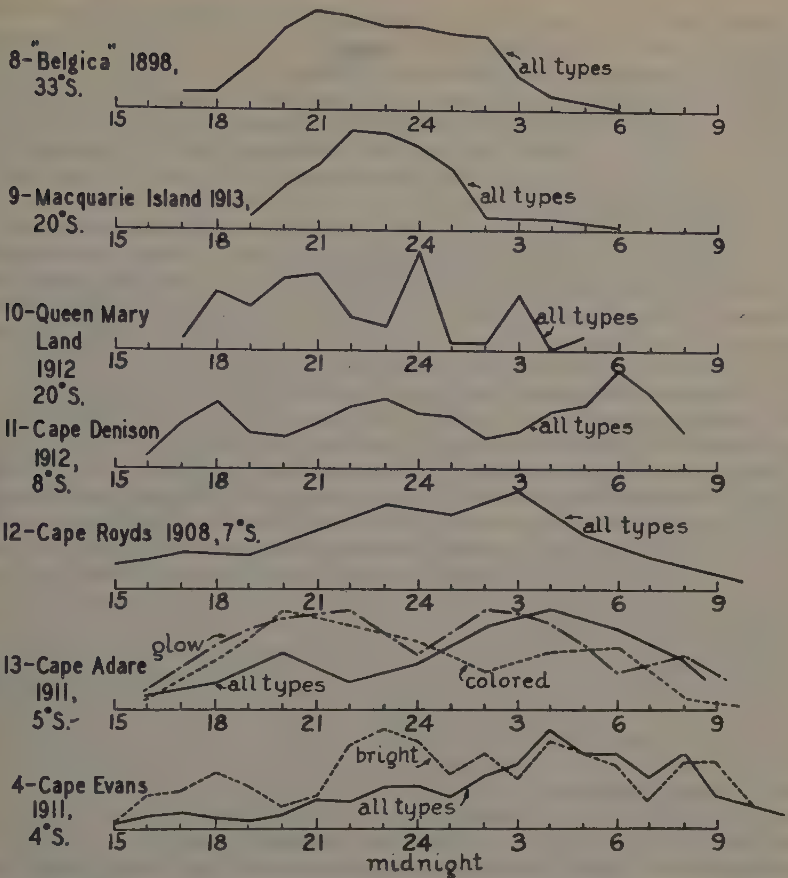
[3]Researches of the Department of Terrestrial Magnetism, Carnegie Inst. Wash. Pub. 175, 6 (1927).



Figs. 1–7

limits, quiet but occasionally of pulsating brightness; *arcs*—quiet bands, generally crossing the sky from horizon to horizon; *rays*—isolated rays or streamers, generally changing rapidly; *curtains*—rapidly moving forms, frequently similar to an arc, or a fraction of an arc, but characterized by a wave-like appearance of the lower rim and by varying intensity; *corona*—rays or curtains converging to a point near the zenith.

The curves of Figures 1 to 6 are from the separate reports of the respective stations of the International Polar Expedition of 1882-1883. Since the stations were all in the arctic regions the auroral observations were made during the winter months from October 1882 to April 1883. The reports give a complete log of the observations and in the case of Jan Mayen and Cape Thordsen a careful analysis of the observations. All the curves of Figure 2 are from the Jan Mayen report (vol. 2, Table III, p. 224). The "ray" and "glow" curves of Figure 3 are from the Cape Thordsen report (p. 190). The Godthaab report gave only a table (p. 14), of all types of aurorae divided into feeble, moderate and strong.



FIGS. 8–14

These all show much the same diurnal variation with a mild maximum at about 21^{h} and have been added together to give the "all types" curve, Figure 4. The reports of Bossekop, Kingua Fjord, and Fort Rae contained no summaries or analyses of the observations. However, Vegard[4] went over the logs of all the stations and counted the occurrences of the ray forms, such as rays, coronas, and curtains; all the curves of Figures 1, 5, and 6 and the corona curves of Figures 3 and 4 are from his paper.

Figure 7 gives the curves obtained by the *Maud* Expedition (*loc. cit.* 3, Table 83, p. 508) from observations in the Arctic Ocean north of Siberia. The curves are the means of the curves for the winter months of the years 1922 to 1925 in geographic latitudes from about 70° to 75° north and longitudes 160° to 173° east, a region about 25° to 30° from the north magnetic pole. The curves for the three separate years were much the same, and therefore the final average curves of Figure 7 must be given great weight. We may supplement Figure 7 by Sverdrup's de-

[4]Phil. Mag., 23, 211-237 (1912).

scription (*loc. cit.* 3, p. 508) of the general course of an average auroral display as seen by the *Maud*. "It begins in the late afternoon with an arch and perhaps a few curtains. Between 20^h and 22^h the display increases in intensity, curtains become more frequent, the streamers and glows appear. Around midnight the display is most brilliant and the moving forms predominate. These disappear in the later part of the night, and in the early morning hours we frequently find only a glow or an arch left."

In Figures 1 to 6 we see a sort of general shift of the maximum of the curves towards the later hours of the night as the latitude increases from the zone of maximum auroral frequency towards the magnetic pole. We can not put this down as a general rule, however, for the curves of Figure 7 do not fall in with such a scheme; if they were to do so their maxima should occur before midnight, as in the curves of Figures 1, 2, and 3, whereas the maxima are actually after midnight. Vegard[4] found, if the prominent maxima at about 6^h of the curves of Figure 5 were left out of account, that the maxima of the curves of Figures 1 to 6 fell within about an hour of local magnetic midnight. Sverdrup (*loc. cit.* 3, p. 506) pointed out that the curves of Figure 7 agreed with Vegard's conclusion, for magnetic midnight was near 24^h on the *Maud*. The maxima of the curves of the stations in the southern hemisphere, on the contrary, show no connection with magnetic midnight, for local magnetic midnight is roughly at 24, 24, 20, 22, 10, 7, and 11 hours, respectively, for the stations of Figures 8 to 14.

The curves of Figures 8 to 14 refer to observations in the southern hemisphere during the winter months from April to September. The curve of Figure 8 is from observations[5] made in 1898 on the ship *Belgica* in mean geographic latitude about 70° south and longitude 86° west. Figures 9, 10, and 11 are from Sir Douglas Mawson's report of the Australasian Antarctic Expedition[6]. Mawson pointed out that the peaks at 18, 21, 24, and 3 hours of the curve of Figure 10 were due to the fact that more observations were made at these hours than in the intermediate period. Thus the auroral occurrence at the Queen Mary Land station might be better represented by a smooth curve through the jagged points of Figure 10, and would be similar to that at Macquarie Island, Figure 9. The curves of Figures 13 and 14 are from Wright's report[7] and Figure 12 is from Mawson's record at Cape Royds[8].

The "all types" curves of Figures 8 to 14 of course do not give the diurnal variation of the separate auroral forms. This is given roughly by the descriptions in the various reports. The stations of Figures 11, 12, and 13 were all about the same distance from the magnetic pole, the sequence of auroral phenomena was much the same at the three stations, and we may take Mawson's very clear description (*loc. cit.* 6, p. 173) of the sequence at Cape Denison as being also representative of Cape Adare and Cape Royds. He recognized a quiet-day progression and a storm-period. The quiet-day sequence consisted of pale nebulous bands, often curtained. These began with relative abundance in the late afternoon hours, fell off after 6 P. M. and increased at about 8 P. M.

[5]H. Arctowski, Voyage du S. Y. *Belgica* (1901).

[6]Australasian Antarctic Expedition 1911-14, Sci. Rep., Ser. B, **2**, Part 1 (1925).

[7]British (Terra Nova) Antarctic Expedition 1910-13, "Observations on the Aurora" (1921).

[8]Mawson, British Antarctic Expedition 1908, Adelaide, S. Aust., Trans. R. Soc., **40**, 151 (1916).

After this they waned in intensity and revived again at 3 A. M. reaching a maximum between 4 and 6 A. M. The appearance of many parallel bands in the zenith was characteristic of the morning hours. During storm-periods the most intense manifestations were reserved for the evening hours. From 9 to 11 P. M. intense colored curtains rise slowly from the north to, and beyond, the zenith. "So irregular in their appearance and so intense are the phenomena of these auroral storms of the evening hours, that they give the impression of being special phenomena superimposed upon a regular and normal quiet cycle. They are the spectacular elements of auroral manifestations and grip the mind, diverting attention from the more natural and regular sequence of diurnal events." The storm-periods usually, but not always, occurred during world-wide magnetic storms.

At Macquarie Island the period of brilliant aurorae corresponded closely with that of Cape Denison, the hour between 10 and 11 P. M. being specially favored, though very brilliant displays appeared at all hours between 8 P. M. and midnight. At the Queen Mary Land station the period of intense, active, and colored aurorae was later in the evening than at Cape Denison. Practically all the more brilliant demonstrations were recorded between 11:30 P. M. and 3:30 A. M., the most favored time being between midnight and 1 A. M. (*loc. cit.* 6, pp. 160 and 161). The bright aurorae at Cape Evans, as shown in the dotted curve of Figure 14, appeared to be somewhat differently distributed through the night than at the stations Cape Adare and Cape Royds. Wright remarked (*loc. cit.* 7, p. 20), "There can be no doubt that the intrinsic brilliancy of the aurora was far greater at Cape Adare than at Cape Evans."

The aurorae seen in temperate latitudes are practically always associated with world-wide magnetic disturbances and thus perhaps are to be thought of in connection with the intense displays of polar latitudes. Chree (*loc. cit.* 1, p. 930) concluded that an excess of evening over morning auroral occurrences is the normal state of affairs in temperate latitudes. In agreement with this Barnard's observations[9] at the Yerkes Observatory, latitude 42°.6 north, scattered through the years 1902 to 1909 showed [10] that, out of 100 nights for which the record seemed to be fairly complete, aurorae were seen on 62 nights between 9 and 11 P. M., on 31 nights around midnight, and on 52 nights in the early morning hours.

Whether the auroral characteristics of a locality are repeated each year, or whether they change from year to year, is difficult to say with any certainty, for there are few complete auroral records from any one station covering a period of years. Wright stated (*loc. cit.* 7, p. 18) that the auroral frequency at Cape Evans for 1912 was much the same as for 1911, Figure 14, although the observations for 1912 were very scanty because of extraordinarily unfavorable weather. He noted (*loc. cit.* 7, p. 14) that the observations by Bernacchi on the Scott Expedition made at a point "not far removed" from Cape Evans in 1902 agreed with Figure 14, and those made in 1903 agreed in that they showed a maximum in the early morning hours, but disagreed in that they showed no maximum in the evening hours. The *Maud* Expedition found[3] that the

[9]Astroph. J., **31**, 208-233 (1910).

[10]Hulburt, Phys. Rev., **34**, 344–351 (1929).

diurnal auroral distribution was much the same for the three winters from 1922 to 1925 although the *Maud* was in somewhat different localities during the three winters. Thus we may venture the conclusion that the auroral characteristics of a locality do not change very much with the years, remembering, however, that such a conclusion is based on very few observations.

On looking over the facts collected in the foregoing paragraphs and keeping in mind possible variances due to different observers, possible vagueness due to the difficulty of classifying auroral forms, and many omissions in the observations due to unfavorable weather, etc., it is concluded that Vegard's[2] conclusion (*a*), that most auroral forms show an evening and morning maximum, is contradicted almost as often as it is upheld. Vegard's[2] conclusion (*b*), that the intense, moving, and strongly colored forms are more frequent in the evening than in the morning, the diffuse weak and quiet forms being more abundant in the morning, is valid for the observations at Cape Royds, Cape Adare, Cape Denison, Cape Thordsen and on the *Maud;* the observations at the other stations appear to be either non-commital, incomplete, or insufficiently analyzed for one to say how they bear on the matter. On the whole one is impressed not so much by the uniformity, but rather by the lack of uniformity in the diurnal course of an auroral display at the various stations. The impression is strengthened by the fact that the auroral display showed characteristics apparently peculiar to the station, appearing in certain favored directions which were different at the various stations, sometimes being related to the topography of the land. For example, Mawson (*loc. cit.* 8, p. 210) observed at Cape Royds that "arcs and bands stretching in straight lines over the sea towards Ross Island generally showed deflections where they passed vertically over the land. . . . Curtains whose direction carried them across the highlands ot the island often appeared to rise locally as if, in some measure, following the surface contour of the island."

Thus, as far as we can tell, the auroral observations seem to indicate that the auroral displays at each locality had characteristics which depended somewhat on the locality, as would be the case if they depended upon the physical state of the upper atmosphere of the locality. This conclusion is in keeping with the general view of the ultraviolet theory[11] of aurorae and magnetic storms which suggested (*loc. cit.* 10, p. 351) that "The emission of the auroral light may not depend simply upon an energy influx carried by ions, but may require in addition that the atmosphere into which the ions fall be in a suitable and perhaps critical condition, such a condition being an erratic function of wind-currents and the states of excitation of the molecules and atoms of the upper atmospheric gases." Of course, the ultraviolet theory has not been developed to the point where it can offer an explanation of details of the aurora, such as bands, patches of luminosity, etc., any more than meteorology can explain the appearance of a particular cloud in a particular spot in the sky.

Naval Research Laboratory,
Washington, D C.,
January 3, 1931

[11]Maris and Hulburt, Phys. Rev., **33**, 412–431 (1929); Hulburt, Phys. Rev., **34**, 344-351 (1929) and **36**, 1560-1569 (1930).

VARIATION OF HORIZONTAL-INTENSITY VARIOMETER SCALE-VALUE WITH TEMPERATURE

By George Hartnell

Abstract—In a paper on horizontal-intensity variometers the author developed the mathematical relations underlying the operation of horizontal-intensity variometers and showed how, in the case of quartz-filament suspension, the scale-value may be controlled and compensation for temperature secured by use of suitably placed auxiliary magnets. Further development of the formulas shows that if too large a filament is used, change of temperature may have an appreciable effect on the scale-value.

Introduction[1]—In his paper[2] "Horizontal-intensity variometers" Mr. Hartnell developed the mathematical relations underlying the operation of horizontal-intensity variometers and showed how compensation for temperature may be secured and, in the case of quartz-filament suspension, how scale-value may be controlled by the use of suitably placed auxiliary magnets.

To test the validity of his conclusions a variometer equipped with control-magnets was operated for nearly a year at Cheltenham in a small uninsulated building and its record compared with that of the standard observatory-instrument, of similar design but without temperature-compensation, in the variation-building where the temperature was maintained nearly constant. The results of these tests were presented in an article[3] entitled "An intensity-variometer corrected for temperature" and showed this method of temperature-compensation to be very satisfactory.

This article discussed the possible effect of change of temperature on scale-value. Four quantities which vary with temperature enter into the scale-value formula: (1) The magnetic moment of the suspended magnet; (2) the magnetic moment of the control-magnet; (3) distance between the two magnets; and (4) rigidity of the quartz filament. It was concluded that temperature-changes in (3) and (4) are so small as compared with (1) and (2) as not to require consideration, but an equation was developed showing the effect on the scale-value of change in the temperature of the magnets. Since the temperature-coefficients of the magnets are of the order of 0.0004, it was considered that this effect would be negligible.

In June 1928 a different *H*-variometer was installed at Cheltenham, in which a larger quartz filament was used in order to eliminate the variation of scale-value with ordinate, according to the method suggested in the publication[2] on horizontal-intensity variometers. The observed scale-values since that time have shown a seasonal change, closely related to changes of temperature. Mr. Hartnell was asked to give further consideration to possible temperature-effects, with the results presented below.

[1]By Daniel L. Hazard, Assistant Chief, Division of Terrestrial Magnetism and Seismology, U. S. Coast and Geodetic Survey.

[2]Special Publication No. 89, U. S. Coast and Geodetic Survey (1922).

[3]George Hartnell, Terr. Mag., 30, 117-124 (1925).

(1) *Symbols*—

M_{0s} = magnetic moment of suspended magnet at zero

q_s = temperature coefficient of suspended magnet

M_s = $M_{0s}(1 - q_s t)$ = moment of suspended magnet at temperature t

M_0' = magnetic moment of sensitivity-magnet at zero

q' = temperature-coefficient of sensitivity-magnet

M' = $M_0'(1 - q't)$ = moment of sensitivity-magnet at temperature t

r = distance between centers of magnets

h = torsion-factor of filament

ϵ = value in radian of one mm on magnetogram

s = scale-value in gammas per mm

s_0 = scale-value without sensitivity-magnet

Δs_0 = change in scale-value due to sensitivity-magnet

F = $\dfrac{2M'}{r^3}$ = field-intensity along axis of sensitivity-magnet

(2) *Scale-value equation*—When the sensitivity-magnet reduces the scale-value and is in line with the suspended magnet, the scale-value equation given in paragraph 4 of the article[3] "An intensity-variometer compensated for temperature" may be written in the form

$$s = \left[\frac{h}{M_{0s}}(1 + q_s t) - \frac{2M_0'}{r^3}(1 - q't)\right]\epsilon \times 10^5 \qquad (1)$$

Factors involving the effect of temperature on the filament and the distance between the magnets have been omitted as negligible.

From the publication[2] "Horizontal-intensity variometers" we have the following relations

$$F_\gamma = \frac{2M'}{r^3} \times 10^5$$

$$s_0 = \frac{h}{M_s}\epsilon \times 10^5$$

$$\Delta s_0 = F_\gamma \epsilon$$

Using these in (1) we obtain our final scale-value equation

$$s = s_0(1 + q_s t) - \Delta s_0(1 - q't) \qquad (2)$$

Differentiating (2) we obtain the temperature-coefficient for the scale-value

$$\frac{ds}{dt} = s_0 q_s + \Delta s_0 q' = s_0(q_s + q') + sq' \qquad (3)$$

s in the last term being the scale-value at zero. As a particular case, if $q_s = q'$

$$\frac{ds}{dt} = (s_0 + \Delta s_0)q' = (2s_0 - s)q' \qquad (4)$$

If the temperature-coefficient of the scale-value is to be zero, we have from (3)

$$s = \frac{q_s + q'}{q'} s_0 \tag{5}$$

and if the temperature-coefficients of the magnets are equal

$$s = 2s_0$$

For example, in order to secure a scale-value of 3.00γ unaffected by change of temperature, it would be necessary to have $s_0 = 1.5\gamma$; that is, the sensitivity-magnet would have to be reversed so as to decrease the scale-value.

Of course the scale-value is affected by temperature even if the variometer is sensitive enough without a sensitivity-magnet. In this case $s_0 = s$, and from (3)

$$\frac{ds}{dt} = sq'$$

For $s = 3.00\gamma$, $q' = 0.00050$ and a temperature-range of 20°, the change in scale-value would be 0.03γ, which would not be objectionable.

As the difference between s_0 and s becomes greater, however, the effect increases. For $s_0 = 20.0\gamma$, $s = 3.00\gamma$, $q_s = q' = 0.00050$ we have from (4) for a range of 20°

$$\Delta s = 0.36\gamma$$

(3) *Cheltenham variometers*—For the *H*-variometer in operation at Cheltenham for about a year prior to July 1928, the scale-value was independent of ordinate and temperature-effects were not noticed. This is not surprising, since for this instrument $s_0 = 9.2\gamma$, $s = 2.92\gamma$, and the temperature-range was only about 10°. Using these values and $q' = 0.00037$ in (4), the expected range of scale-value would be only 0.06γ.

When another variometer was installed in June 1928, a relatively large filament was used in order to secure a scale-value independent of ordinate. Also, no special effort was made to control the seasonal variation of temperature in the room, so that it increased to over 15°. Under these conditions a variation of scale-value became apparent. It is clearly shown in the accompanying diagram, where temperature and

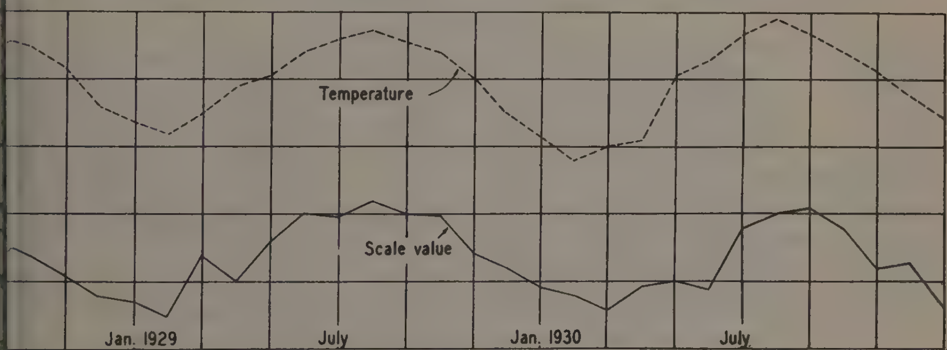


FIG. 1

scale-value (determined monthly) are plotted side by side for the period from July 1928 to January 1931. This relation is represented fairly well by the formula

$$s = 2.82\gamma + 0.0092\ (t - 20°)$$

For this variometer $s_0 = 18.0\gamma$, $s = 2.82\gamma$, and $q' = 0.00037$. The temperature-coefficient of the suspended magnet, q_s, was not determined, but if we assume $q_s = q'$, we obtain by substituting in (4)

$$\frac{ds}{dt} = (36.0 - 2.82)\ 0.00037 = 0.0123$$

By referring to (3) it will be seen that this value would be increased or decreased according as q_s is greater or less than q'. Considering all the various factors involved, this may be regarded as a reasonable agreement with the result obtained from the observations.

Cheltenham Magnetic Observatory,
U. S. Coast and Geodetic Survey,
January 1931

ATMOSPHERIC-ELECTRIC SURVEY IN THE VICINITY OF WASHINGTON, D. C.

By H. F. Johnston and G. R. Wait

Abstract—Atmospheric-electric observations obtained through a survey in the District of Columbia and vicinity, indicate the existence of high-, medium-, and low-conductivity areas. Approximately normal high total conductivity-values, on the average 2.3 × 10^{-4} E.S.U., were found in regions outside the District of Columbia. This value is about three times that for the low-conductivity region which is roughly included by the District boundary-lines, except for an extension towards the city of Baltimore. The total air-earth current tends towards equality over all three regions; this was interpreted to mean that the factor causing subnormal conductivity is operative to only small altitudes. The results suggest that atmosphereic pollution may be a large factor in producing small conductivities in the low area and that the subnormal values at the Washington Observatory of the Department of Terrestrial Magnetism, 16 meters above the surface of the ground, are in addition affected by a lower rate of ionization than are those nearer the Earth's surface.

When the total air-earth current is computed from the potential gradient and the total conductivity, true values will be obtained only at stations where there are undisturbed equipotential surfaces. Where disturbances exist in the equipotential surfaces, a reduction-factor for conductivity as well as for potential gradient will be required in order to compute true values of air-earth current for the reduction-factor station. The reduction-factor for the conductivity as recorded at the Washington Observatory, based on the series of intercomparisons with all survey-stations reported upon, is about 4; this large value is due probably to the unusual height of the apparatus above the surface of the ground. For measurements of potential gradient and of the conductivity made at similar heights above the ground and sufficiently near each other, probably no great error results by assuming a value of unity for the reduction-factor, that is, when the air-earth current is computed from the potential gradient and conductivity.

The electrical conductivity of the atmosphere varies over wide limits from place to place over the continents, even when no great change in altitude is encountered. The total air-earth current is much more constant than the total conductivity. Tables 1 and 2 as given by Benndorf and Hess[1] provide data to emphasize these facts. In addition, Table 3 gives values for both the total conductivity and the calculated air-earth current at various temporary eclipse-stations and permanent observatories occupied by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The values tabulated for the four eclipse-stations are based in all cases upon measurements extending

Table 1—*Mean values of total conductivity according to Benndorf and Hess*

Place	Year	Altitude above sea-level	$(\lambda_+ + \lambda_-)$	$\lambda_+/\lambda_- = q_\lambda$	Observer	Method
		meters	$ESU\times10^{-4}$			
Salzburg), Austria	1908–20	420	2.64	1.02	E. Schweidler	Dissipation
witzerland	1910	1,600	2.8	1.13	C. Dorno	Schering
Switzerland	1913–15	580	2.5	1.08	A. Gockel	Dissipation
„ Germany	1910–11	80	0.95	1.16	K. Kähler	Schering
Scotland	1908	170	1.1	.....	C. T. R. Wilson	Indirect
mark, Greenland	1907–08	8	5.5	1.28	A. Wegener	Apsiration
Porto Rico	1907–08	150	3.7	1.02	K. W. F. Kohlrausch	Aspiration
Rhenania, Argentina	1912	<200	2.6	1.02	G. Berndt	Dissipation
quitos, Amazon River	1914	<100	0.68	0.97	G. Berndt	Dissipation
moa	1910	2	4.5	1.04	G. Angenheister	Aspiration
ual	1911	0	3.1	0.85	G. Angenheister	Aspiration
a Quimsacruz, Bolivia	1909	5,200	10.8	2.0	W. Knoche	Indirect
. Haven, Spitzbergen	1913–14	<100	4.95	1.33	K. Hoffmann	Schering

[1] r-Pouillet, Lehrbuch der Physik, 5, I, 537 and 646 (1928).

TABLE 2—*Mean values of air-earth current-density according to Benndorf and Hess*

Place	Year	Air-earth current-density	Method
		$ESU \times 10^{-7}$	
Icking (near Munich), Germany	1901	5.1	Direct
Peebles, Scotland	1906–07	6.6	Direct
Simla, India	1909	5.4	Direct
Munich, Germany	1909	3.0	Direct
Edinburgh, Scotland	1909	4.2	Direct
Kew, England	1922	2.2	Direct
Göttingen, Germany	1906	8.1	Indirect
Apia, Samoa	1907–08	6.3	Indirect
Potsdam, Germany	1910–11	5.8	Indirect
Thingeyrie, Iceland	1910	9.0	Indirect
Davos, Switzerland	1910	5.1	Indirect
Buenos Aires, Argentina	1911	3.9	Indirect
Seeham (Salzburg), Austria	1908–20	6.9	Indirect
Freiburg, Switzerland	1913	9.5	Indirect
Tortosa, Spain	1914–24	6.7	Indirect

over an interval of a few hours each day for a period of a week or less; those for the four permanent observatories are based upon more extended series of observations. It should be noted that the Washington Observatory at the Department of Terrestrial Magnetism was established primarily to test and improve atmospheric-electric apparatus, although it is not in an altogether satisfactory location for investigating undisturbed atmospheric-electric variations. The total air-earth current in all cases was obtained by the so-called indirect method, that is, through the product of the total conductivity, $(\lambda_+ + \lambda_-)$, and the potential gradient, P; the monthly values were obtained from the means of the total conductivity and the means of the potential gradient for each corresponding month.

Table 3 shows that the total conductivity for Washington is extremely low and that the product of the total conductivity and the potential gradient is much below that for any other station. The recording conductivity-apparatus at Washington is mounted in the Deck-Observatory on the roof of the laboratory of the Department of Terrestrial Magnetism,

TABLE 3—*Mean values of total conductivity and air-earth current-density at stations occupied by the Ca[rnegie] Institution of Washington*

Place	Time of observations	Char. series	Latitude	Longitude	Altitude above sea-level	Total conductivity, $(\lambda_+ + \lambda_-)$	Potential gradient, P	Air-e[arth] curr[ent-] densi[ty] i
			° ′	° ′	*meters*	$ESU \times 10^{-4}$	v/m	*ESU*[…]
Lakin, Kansas	Jun 1918	Eclipse	37 53 N	101 18 W	910	7	56	13[…]
Sobral, Ceara	May 1919	Eclipse	3 42 S	40 21 W	<100	6	30	6[…]
Point Loma, Cal.	Sep 1923	Eclipse	32 40 N	117 15 W	140	2.3	300	23[…]
Greenport, N. Y.	Jan 1925	Eclipse	41 06 N	72 22 W	2	1.2	225	9[…]
Watheroo, W. A.	Jan-Dec 1929	Obs'y	30 19 S	115 52 E	244	3.3	86	9.[…]
Huancayo, Peru	Jun-Dec 1929	Obs'y	12 03 S	75 20 W	3,350	9.8	49	16[…]
Tucson, Arizona	Oct 1929	Obs'y	32 15 N	110 50 W	770	5.2	35	6[…]
Washington, D. C	Jan-Jun 1930	Obs'y	38 57 N	77 04 W	95	0.25	156	1.[…]

[a]As computed by formula, $i = P\,(\lambda_+ + \lambda_-)/(3 \times 10^{9})$.

Table 4—*Miscellaneous data pertaining to atmospheric-electric stations in District of Columbia and vicinity*

Station			Date	Altitude above sea-level	Position with respect to D.T.M. observatory		Wind		Clouds	
Group	No.	Name			Direction	Distance	Direction	Force[a]	Kind	Amount[b]
			1930	*meters*		*km*				
I	1	Rock Creek Park	Oct 9	96	E by N	0.9	NW	3	Str	10
	2	D.T.M. grounds	13	84	E ½ N	0.1	SE by E	1	Cu	7
	3	D.T.M. observatory	14	95	....	0.0	NE	1	A-Str Fr-Cu	9
	4	Chevy Chase Golf Club	24	107	NW ¼ W	2.9	NW	2	Fr-Cu	10
	5	Pinehurst	24	81	N ¼ W	2.3	NW	2	Fr-Cu	8
	6	Riggs Estate	30	17	E ½ N	7.6	S	1	A-Str	4
	7	College Park	30	14	E by N	12.4	....	0	A-Str	10
	8	Laurel Sanitarium	30	67	NE ¼ E	23.1	....	0	A-Str	1
	9	Capitol View	31	30	SE by E	13.7	NW	3	Cu	3
	10	Riggs Mill	Nov 1	41	ENE	8.7	NW	4	Cu	4
	11	4109 Garrison St., D. C.	1	105	W ¾ S	1.5	NW by W	2	Cu	3
II	12	Huyett	Oct 8	171	NW ½ N	102.0	SE	3	Str	9
	13	Pohick Church	17	27	SSW ¼ W	30.2	S	1	A-Str	10
	14	Cheltenham	31	55	SE ½ S	31.4	NW	4	A-Str	10
	15	Glenmark Park	Nov 1	94	W ¾ S	2.3	NW by W	4	Cu	7
III	16	Urbana	Oct 15	128	NNW ¾ W	48.1	N	1	A-Str Cu	3
	17	Gaithersburg	15	158	NNW ½ W	21.7	....	0	A-Str	1
	18	Congressional Airport	15	108	NNW ½ W	12.2	....	0	......	0
	19	Merrifield	17	105	SW by W ¼ W	18.5	S	2	A-Str	10
	20	Fort Meyer	17	64	S by W	9.0	NW	3	A-Str	10
	21	Mitchellville	31	37	E	31.4	NW	4	A-Str	10
	22	Indian Spring Golf Club	Nov 1	101	NE by N	7.6	SW by S	1	......	0

[a]Beaufort scale. [b]Scale of 10.

Table 5 *Summary of atmospheric-electric data at stations in the District of Columbia and vicinity*

Station No.	75° west meridian mean time	Penetrating-radiation, R	Aitken nuclei per cc, N	Potential gradient, P	Conductivity $\lambda+$	Conductivity $\lambda-$	Conductivity $(\lambda+ + \lambda-)$	Air-earth current-density,[a] i	Simultaneous values at Washington Observatory: Potential gradient, P	Conductivity $\lambda+$	Conductivity $\lambda-$	Conductivity $(\lambda+ + \lambda-)$	Air-earth current-density,[a] i	Ratio station i to observatory i
	h h	(ions/cc / s)		v/m	$ESU\times10^{-4}$			$ESU\times10^{-7}$	v/m	$ESU\times10^{-4}$			$ESU\times10^{-7}$	
1	10.4–10.8	....	....	165[c]	0.45	0.30	0.75	4.1	165	0.18	....	0.32	1.8	....
2	12.4–13.9	....	....	224[c]	0.46	0.38	0.84	6.3	224	....	0.12	0.28	2.1	....
3	14.5–16.0	....	.....	237[b,c]	0.43[b]	0.20[b]	0.63[b]	5.0[b]	237	....	0.16	0.37	2.9	....
4	11.4–12.4	4.20	53,000	149	0.48	0.46	0.94	4.7	148	....	....	....	....	....
5	14.5–15.6	3.50	13,400	154	0.42	0.42	0.84	4.3	127	....	....	....	....	....
6	12.0–12.7	4.23	60,500	153	0.53	0.44	0.97	4.9	154	....	0.16	0.37	1.9	2.6
7	14.6–15.5	4.01	34,500	280	0.34	0.34	0.68	6.3	227	....	0.12	0.28	2.1	3.0
8	16.8–17.1	3.53	104,000	136	0.26	0.28	0.54	2.4	181	....	0.08	0.19	1.1	2.2
9	10.2–10.8	3.36	35,000	257	0.44	0.49	0.93	8.0	80	....	0.17	0.39	1.0	8.0
10	11.4–12.2	3.85	12,100	119	0.42	0.46	0.88	3.5	123	....	0.13	0.30	1.2	2.9
11	17.1–17.8	....	100,000	....	0.42	0.42	0.84	....	134	....	0.13	0.30	1.3	...
Means........		3.81	51,600	182	0.42	0.40	0.82	4.9	164	....	0.13	0.31	1.7	....
12	12.0–14.0	4.61	9,400	42	0.71	0.73	1.44	2.0	183	0.17	....	0.30	1.8	1.1
13	10.2–11.3	3.63	10,200	118	1.00	0.63	1.63	6.4	463	....	0.06	0.14	2.2	2.9
14	13.2–13.9	2.76	4,600	70	0.80	0.82	1.62	3.8	62	....	0.09	0.21	0.4	9.5
15	15.6–16.3	....	6,000	....	0.95	0.95	1.90	...	122	....	0.14	0.32	1.3	...
Means........		3.67	7,600	77	0.86	0.78	1.65	4.1	208	....	0.10	0.24	1.4	...
16	10.3–11.4	4.60	21,200	90	1.06	1.02	2.08	6.2	125	....	0.21	0.49	2.0	3.1
17	13.8–14.2	4.96	......	47	1.02	1.01	2.03	3.2	106	....	0.19	0.44	1.6	2.0
18	15.4–16.5	3.40	......	57	1.26	0.88	2.14	4.1	136	....	0.19	0.44	2.0	2.0
19	13.9–14.8	4.18	4,100	98	1.70	1.51	3.21	10.5	118	....	0.28	0.65	2.5	4.2
20	16.1–16.5	....	9,200	....	1.28	1.17	2.45	.....	123	....	0.20	0.46	1.9	...
21	16.0–16.5	3.67	4,800	45	1.02	1.14	2.16	3.2	62	....	0.13	0.30	0.6	5.3
22	8.8– 9.2	4.41	5,400	156	1.11	1.16	2.27	11.8	195	....	0.16	0.37	2.4	4.9
Means........		4.20	8,900	82	1.21	1.13	2.33	6.5	124	....	0.19	0.45	1.9	3.8

[a] As computed by formula, $i=P\,(\lambda_+ + \lambda_-)/3\times10^4$. [b] Value not included in the mean. [c] Observatory values.

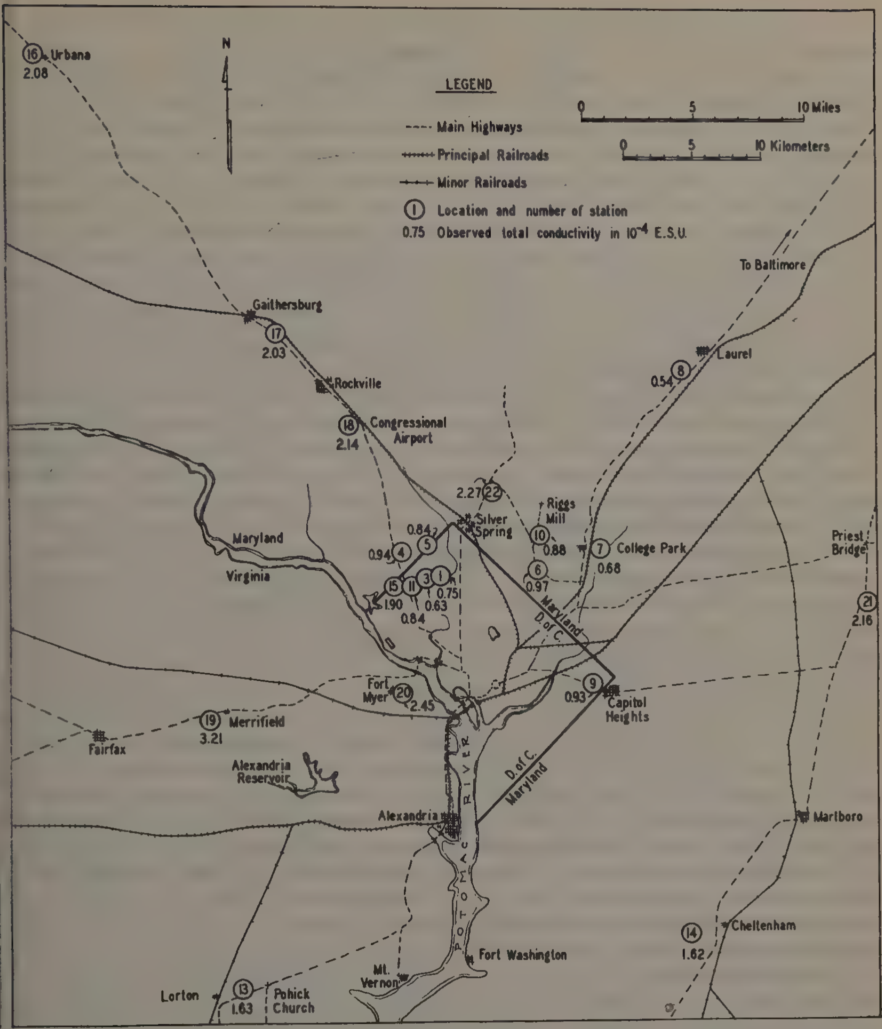


FIG. 1—Sketch-map of District of Columbia and vicinity showing stations

16 meters above the general ground-level. The laboratory is on a prominent hill about nine kilometers to the northwest of the main business district of Washington. It was considered important to determine the causes of the extremely low conductivity being recorded and as an initial step in this direction, an atmospheric-electric survey of the region immediately surrounding the Observatory was made by the authors using portable equipment. The complete program at the majority of the stations included determinations of the two conductivities by a hand Gerdien apparatus, the potential gradient using the stretched-wire method of Simpson and Wright applying the leak-free procedure as suggested by Gish and Sherman[2], the number of condensation-nuclei

[2]Terr. Mag., 34, 231-237 (1929).

per cubic centimeter using an Aitken pocket counter, and penetrating-radiation observations using a Kolhörster apparatus.

Table 4 lists the stations occupied and gives altitudes above sea-level, compass-directions and distances from the Washington Observatory, and the meteorological data. Table 5 summarizes the atmospheric-electric results, the field-stations being grouped on the basis of low, medium, and high conductivity. The mean values of the total conductivity are 0.82×10^{-4}, 1.65×10^{-4}, and 2.33×10^{-4} E.S.U. for the three groups; the last group-value is thus nearly three-fold the first.

Table 5 gives also the values of conductivity obtained with the continuous recording-apparatus at the Washington Observatory for those times when field-values were observed. Since January 1, 1930, it has been the Observatory practice to record positive and negative conductivity during alternate weeks. Since then the average value of the ratio of positive to negative conductivity, λ_+/λ_-, was 1.32 and the value of the total conductivity, $(\lambda_+ + \lambda_-)$, for times simultaneous with the field-observations were computed on this basis. The values of conductivity at the Observatory are much lower than any of the values found in the field; the mean for the Observatory is less than 40 per cent of the mean for the first field-group.

Observations were made October 14, 1930, with the portable Gerdien conductivity-apparatus within a few feet of the continuous recording-instrument. The values of total conductivity obtained with the portable and recording-instrument were 0.63×10^{-4} and 0.37×10^{-4} E.S.U., respectively, which might be taken as an indication that the former instrument gives higher values than the latter. It is to be noted, however, that the direct comparison was for negative conductivity only, the observed values with the portable and recording-apparatus being 0.20×10^{-4} and 0.16×10^{-4} E.S.U., respectively. A few observations for positive conductivity at scattered intervals during the set gave the comparatively high value of 0.43×10^{-4} E.S.U. which, when equally weighted with the longer negative series gives the mean value of 0.63×10^{-4} E.S.U. for the total conductivity. The observed values of negative conductivity with the two instruments are in good agreement. Likewise, on other occasions simultaneous observations with the two instruments have given results that are strictly comparable.

It might be thought advisable to attempt to make adjustments of the field-value of the conductivities in order to correct for variations in absolute value as indicated by the record at the Observatory. In general, however, the field-values do not scatter greatly except in the case of the three lowest values and the highest value. In any case, no information is at hand regarding the general distribution of conductivity-variations, consequently any such adjustment would probably not improve the absolute values.

The individual values of the air-earth current depart less from the mean than any of the other elements except the number of pairs of ions, R, generated inside the penetrating-radiation apparatus. The mean values of the air-earth current for each individual group also agree quite well with each other. This result makes it seem that the rather considerable variation in the conductivity with position must be confined to a relatively thin layer of air near the Earth's surface. In other words, the factor that is causing the low conductivity such as that observed in the low-conductivity group does not seem to operate at very great altitudes.

The total air-earth current-density may be observed by a direct method, but for the stations so indicated in Table 2 and for all in Tables 3 and 4 it is computed indirectly from the product of the potential gradient and the total conductivity. This method is justifiable only under certain definite circumstances. For example, the indirect method is permissible at a station where the equipotential surfaces are undisturbed and where both elements are observed sufficiently near each other and at equal heights. At stations, however, where data obtained with the potential-gradient apparatus require a reduction-factor to convert observed volts to volts per meter, this method is not permissible unless the conductivities at the recording-station and at the reduction-factor station are the same or bear some known relationship to each other. As an illustration, it is necessary to secure a reduction-factor for the potential gradient recorded in the Deck-Observatory at Washington on the top of the Department's laboratory through absolute observations at a reduction-factor station about 900 meters distant in Rock Creek Park. The net effect of applying the reduction-factor thus determined is that the recorded volts are reduced to the equivalent of a potential gradient in volts per meter measured in Rock Creek Park. The conductivity-values recorded in the Deck-Observatory are characteristic of that place and not of Rock Creek Park. If, however, one were to obtain a conductivity reduction-factor, that is, the relationship between the conductivity at the Observatory and that at the station in Rock Creek Park, then it would be possible to compute the air-earth current applying for Rock Creek Park. In other words, to obtain values of the air-earth current by the so-called indirect method, at stations where a potential-gradient reduction-factor is required, it is necessary to have the equivalent of a reduction-factor for the conductivity as well as for the potential gradient.

From the results of the survey, there appear to exist regions of low, medium, and high conductivity in the area covered. The region of low conductivity includes roughly the District of Columbia and a strip extending from Washington towards Baltimore. Six of the stations occupied in the low-conductivity group of eleven are actually outside the confines of the District of Columbia (two of these are less than one and one-half kilometers from the District line and the other four stations are within the strip extending towards Baltimore). As will be seen from Table 5, at Laurel Sanitarium, about midway between Washington and Baltimore, the conductivity was decidedly low. All the stations occupied in the high-conductivity group are outside the District's boundary, as are also those in the intermediate-conductivity group except that at Glenmark Park, which is practically on the District line.

In view of the nearly constant value of the air-earth current at the various stations, it would seem that the variation in potential gradient was in general due to a variation in the conductivity near the Earth's surface. Granting that in the main, the difference in the values of the potential gradient is caused by the difference in the values of the conductivities as one goes from place to place, one may well inquire as to the cause of the great differences in the observed values of the conductivities as shown in Table 5. According to present notions, the cause could be the slow rate at which the small ions are being generated, the rapid rate at which they are being removed, or a combination of the two. Table 5 shows that for the first group the number of condensation-nuclei is large, but is moderate for the other two groups. Using Schweidler's equation,

$q = \alpha n^2 + \omega n N_A$, where q is the rate of ionization, n the number of small ions per cubic centimeter, N_A the number of condensation-nuclei per cubic centimeter, α the recombination-coefficient between the small ions, and ω is proportional to the recombination-coefficient between the small and the large ions, the computed mean value for q is much larger for the first group than for the other two groups, the mean values being approximately 35, 11, and 18, respectively, for the first, second, and third groups. The value 11 is near that which one would ordinarily expect; consequently, if the Schweidler equation actually represents the facts, it seems that the ionization of the atmosphere increases as the concentration of condensation-nuclei increases. This has been commented on by others and P. J. Nolan[3] has suggested a modification of the Schweidler equation which will give values of q that vary more slowly with the concentration of condensation-nuclei. Even if the computed value of q is correct, it is not clear why it should vary with the number of condensation-nuclei. If the Schweidler equation does represent the facts, then it should be altogether possible for the condensation-nuclei, appearing in numbers as observed, to reduce the conductivity to even the lowest obtained on this survey. The number of condensation-nuclei, however, have never been found to be abnormally higher on the roof of the Department's laboratory than nearby on the ground. Consequently in order to account for the differences in conductivity at the Deck-Observatory and near the ground, it may be necessary to postulate a lower rate of ionization at a height equal to that of the Observatory.

The last column of Table 5 gives the ratio of field to Washington-Observatory values of the product of potential gradient and total conductivity. Values from all stations have been included, however distant the station may have been from the Observatory. In conclusion, if the air-earth current at Rock Creek Park and at the other stations were always equal, then this ratio should represent the reduction-factor to reduce the Observatory conductivity to what would be observed at Rock Creek Park. While the values scatter considerably and no great accuracy can be claimed for the mean value, some idea of the general order of magnitude of the conductivity reduction-factor can be gained from it. Many more observations over an extended period will be required to obtain a more accurate value.

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[3]Proc. R. Irish Acad., A, 38, 49-59 (1929).

SOME NEW THEORETICAL AND EXPERIMENTAL RESULTS ON THE AURORA POLARIS

By Ernst Brüche

A recent paper in *Zeitschrift für Astrophysik* reported on the new theoretical investigations[1] undertaken by Prof. C. Störmer and also on experimental research carried out by the author on the theory of the aurora polaris.[2]

The object of the theoretical investigation was to determine the periodic paths in space. The work dealt with types of paths which were hitherto unknown. The experimental research was confined to the practical production of electronic paths by employing models. The experimental results confirmed the theoretical work, and in addition, led to the determination of new paths.

Constant collaboration existed between Prof. Störmer and the author during the experimental research and thus a close co-operation between theory and experiment was ensured.[3] The chief object of the cooperation was to determine the periodic paths and the influence of such paths—which, in their entirety represent a ring-current—on the torus- and impact-zones. Other urgent work unfortunately prevented Prof. Störmer from cooperating in the publication of the combined work. In consequence the author will endeavor to expound at least the principle of the mathematical method as seen by an experimental physicist, and in addition, he will give the theoretical results.

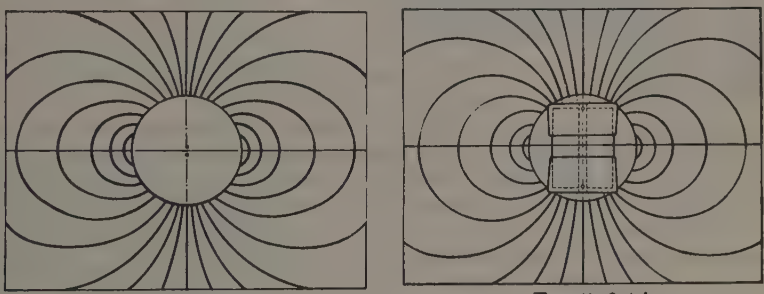


Fig. 1—Comparison between the magnetic fields of an elementary magnet (at left) and of the model Earth

Fundamental Principles—Theory and experiment rest upon the same hypothesis. The given features are an elementary magnet and an electronic ray from which the paths of the electrons in the field of the elementary magnet are to be determined. Whereas the theoretical investigation can be immediately undertaken by mathematical means, it was necessary that experimental means be found to produce the elementary magnet and also a suitable electronic ray. The elementary magnet was realised by a magnetic coil whose field shows a striking similarity to that of an elementary magnet. Figure 1 shows the simi-

[1] C. Störmer, Periodische Elektronenbahnen im Felde eines Elementarmagneten und ihre Anwendung auf Brüches Modellversuche und auf Eschenhagens Elementarwellen des Erdmagnetismus. Zs. Astroph., 1, 237-274 (1930).

[2] E. Brüche, Störmers Polarlichttheorie in Experimenten. Zs. Astroph., 2, 30-69 (1931).

[3] It need scarcely be mentioned that it was the experimental work which especially benefited from the cooperation. The author wishes to take this opportunity to thank Prof. Störmer once more for the interest taken in his experiments.

larity of the formation of the lines of force. Thread-rays of electrons, having a velocity of about 200 volts, were employed. It is now possible to produce experimentally these thread-rays of a sufficient length.[4] Figure 2 shows examples of these rays.

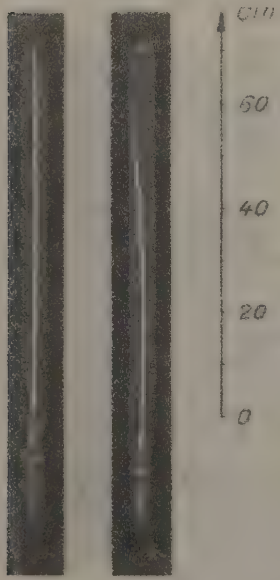


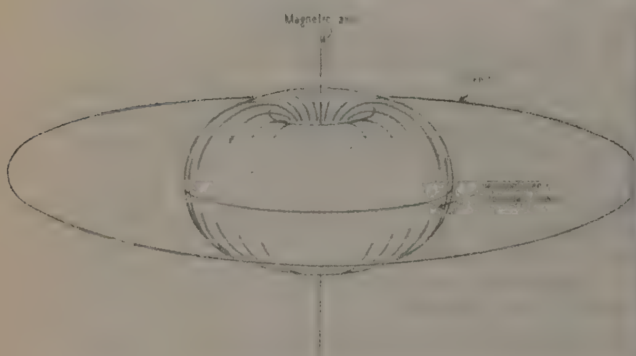
FIG. 2—Thread ray 70 cm in length in a space free from a field (at left) and in the horizontal component of the Earth's field

Before commencing the investigation of the periodic paths, a few fundamental particulars of the theory will be considered in conjunction with the experiments.[5] A simple consideration first shows that a circular orbit (see Fig. 3) must exist at a certain distance in the equatorial plane of the elementary magnet and, furthermore, this path must be concentric with the magnetic equator. This path will occur, therefore, if the radius of curvature is exactly equal to the distance between the electron and the elementary magnet and if the centre of curvature lies in the elementary magnet itself. Combining the equation for the decrease of the field in the equatorial plane and the law for the deviation of electrons, this radius in centimeters is

$$c=\sqrt{(M/v)\ (e/m)}$$

where M is the magnetic moment, v the velocity of the electron, and e/m is the ratio of the charge to the mass of the electron in electro-magnetic units.

The quantity c is chosen as the unit of length for the problem, and is therefore written as 1 throughout the theoretical considerations. In the tests with models where utilisation is made of numerically computed moments of an elementary magnet and real electrons of definite velocity, c is of the



FIGS. 3 AND 4—Diagrammatic representation of the electron-free toroidal space and the orbit and experimentally obtained orbit of the equatorial plane

[4]E. Brüche und W. Ende, Fadenförmige, sichtbare Elektronenstrahlen. Zs. Physik, **64**, 186-190 (1930).

[5]C. Störmer, Corpuscular theory of the Aurora Borealis. Terr. Mag., **22**, 23-34, 97-112 (1917). Twenty-five years' work on the polar aurora. Terr. Mag., **35**, 194-208 (1930).

greatest significance. In the experimental method, the orbit is obtained as shown in Figure 4. If numerical values are substituted, there is, to within a few per cent, a quantitative agreement between the calculated and the experimental fundamental quantities.

The theory shows that electrons which come from infinity can only approach the elementary magnet to any desired degree if certain initial conditions are satisfied. Although the electrons are able to reach the elementary magnet along the axis of the elementary magnet itself, nevertheless, when $c = 1$ the electrons only cover the distance $(\sqrt{2} - 1)$ in the plane of the equator. This can also be verified experimentally using a broad bundle of electrons, as shown in Figure 5. Between the two limiting cases, there exists a transition in the form of a toroidal

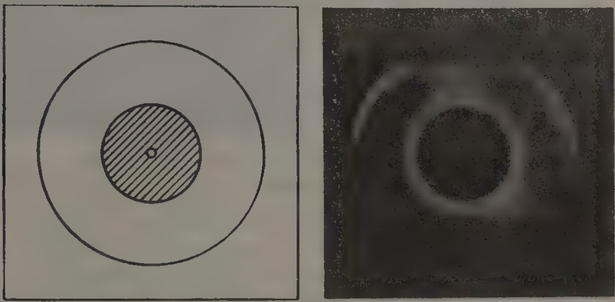


FIG. 5—Connection between the orbit and the limit of approach from theory (at left) and from experiment

space[6] around the elementary magnet which space is free from electrons. Figure 3 shows this diagrammatically drawn to scale with reference to the orbit; Figure 6 shows sections on the meridian for the theoretical and for the experimental cases. The way in which an electronic ray penetrates into the "horns" of such a section and also the way in which it fluctuates between the poles, are shown by suitable projections in Figure 7 as determined from theory and from experiment.[7]

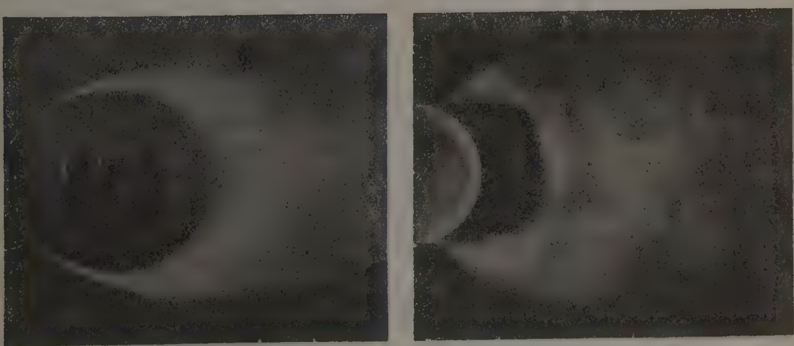


FIG. 6—Section on the meridian through the electronic torus from theory for $\gamma = -0.97$ (at left) and from experiment

[6]C. Störmer, Sur le movement d'un point matériel portant une charge d'électricité sous l'action d'un aimant élémentaire. Skr. Vid. selsk., Kristiania, No. 3 (1904).

[7]C. Störmer, Sur les trajectoires des corpuscles électrisés dans l'espace sous l'action du magnétisme terrestre avec application aux aurores boréales. Arch. Sci. Phys., **24** (1907); **32** (1911); **33** (1912).

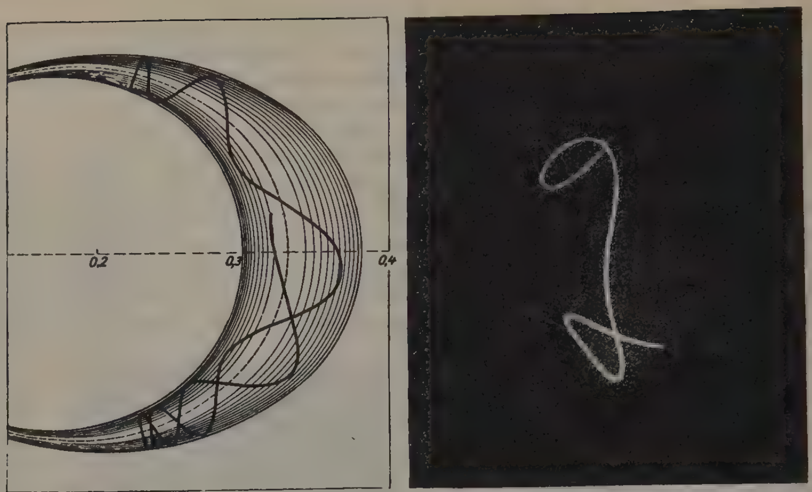


FIG. 7—Oscillation of the electrons between the poles from theory (at left) and from experiment

Method of investigation—Similar methods are employed for investigating the periodic paths both experimentally and theoretically, namely, systematic trial by varying the initial conditions.

When treating the problem mathematically, it is advisable to start from the following consideration. As indicated in Figure 8, the periodic orbit will lie on a closed surface of revolution having the axis of the elementary magnet as its axis. A plane through this axis will cut the surface in a closed curve K. If now the plane is following the motion of the electron in such a manner that the electron is always lying in that plane, the electron will move periodically along the curve K.

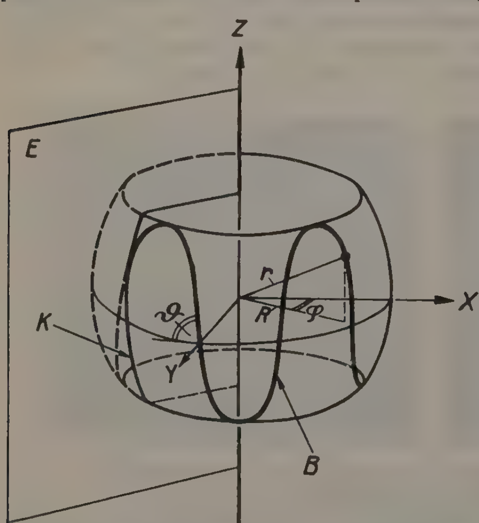


FIG. 8—Sketch of a periodic path with its solid of rotation

Corresponding to these considerations, Störmer transformed the equations of motion from cartesian coordinates to semi-polar coordinates, which gave equations of motions for the plane E and for the electron along the curve K in that plane.

The motion of the plane E is governed by the equation (compare Fig. 8) with the arc as independent variable:

$$R^2 \frac{d\phi}{ds} = 2\gamma + R^2/r^3 \quad (1)$$

In this equation γ is a constant of integration which has a definite numerical value between $-\infty$ and $+\infty$ for any definite path. By introducing the angle Θ between the merid-

ian plane E and the path of the electron this equation can also be written

$$\sin \Theta = 2\gamma/R + R/r^3 \tag{1a}$$

Störmer introduces the auxiliary function

$$Q = 1 - [2\gamma/R + R/r^3]^2$$

Thus

$$\cos \Theta = \sqrt{Q} \tag{2}$$

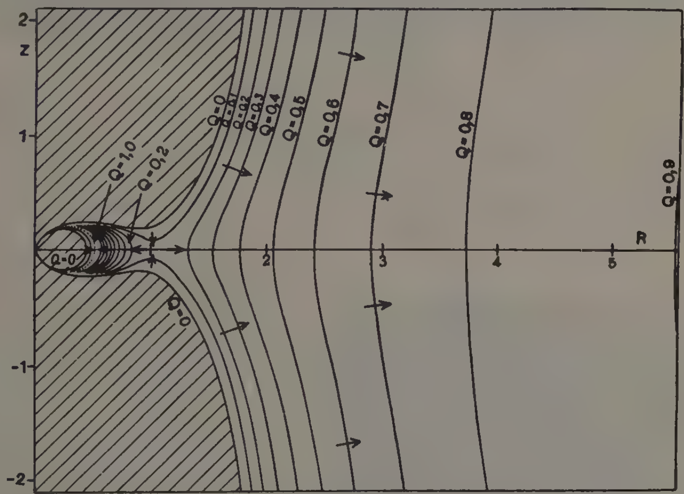
$$\sin \Theta = \pm\sqrt{1 - Q} \tag{3}$$

and we have the following equations for the motion of the electron along the curve K

$$\frac{d^2R}{ds^2} = \frac{1}{2}\frac{\partial Q}{\partial R}, \quad \frac{d^2Z}{ds^2} = \frac{1}{2}\frac{\partial Q}{\partial Z}, \quad \left(\frac{dR}{ds}\right)^2 + \left(\frac{dZ}{ds}\right)^2 = Q \tag{4}$$

By these equations periodic orbits may be determined. For values of sin Θ between -1 and $+1$, the orbit according to equation (1a) must be confined to the region of space where

$$-1 \leqq 2\gamma/R + R/r^3 \leqq 1$$



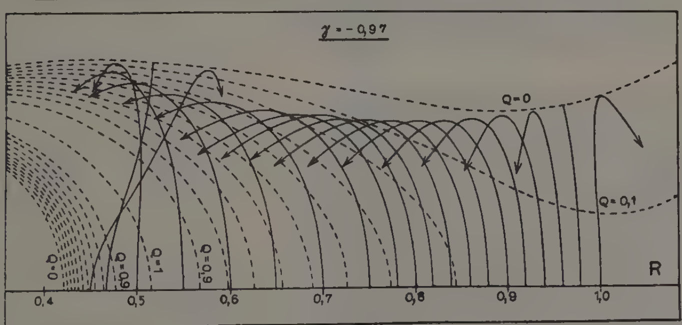


FIG. 9—Sections of the surfaces $Q = a$ by a meridian plane E for $\gamma = -0.97$, according to the theory

FIG. 10—Theoretical investigation of periodic paths for $\gamma = -0.97$

This region can be described by the surface of revolution $Q = a$ by giving successively the constant a all values from 0 to 1. Figure 9 shows the section of these surfaces by the plane E for the case $\gamma = -0.97$.

It is possible to find the path K by direct discussion and numerical integration of equations (4), which is not discussed further in the present paper.

Let us choose, for example, a definite distance R_0 and a definite angle θ between the K-curve and the R_0 axis, for instance, $R_0 = 0.7$ and $\theta = 90°$. The resulting K-curve thus obtained is shown in Figure 10. With these initial conditions, a path which is *not* periodic results because the limit $Q = 0$ is not attained and the path does not close on itself.

How then can the K-curve for a periodic path be found? As this task is not explicitly soluble, the only method of determination is that by trial in which the initial conditions are varied. Störmer, while keeping $\theta = 90°$, varied R_0 until when plotting the corresponding K-curve, it was seen that the conditions for a periodic path were satisfied. With the values $R_0 = 0.4677$ and $R_0 = 0.978$, two of the desired paths were found (Fig. 10).

After having found that when $\theta = 90°$, periodic paths exist for $R_0 = 0.4677$ and $R_0 = 0.978$, it is also possible to calculate the corresponding orbits B in space. The angle Θ at which the orbit in space starts from the equatorial plane, follows from equations 1a and 2. For the special case chosen $R = r = 0.4677$ or 0.978 and $\gamma = -0.97$, the angle Θ becomes 25° or 70°, respectively. The numerical calculation finally leads to the two paths shown in Figures 15 and 13.

The method according to which the periodic paths are found in theory is therefore as follows: First the γ-value of the path is chosen, then the initial conditions—especially the values R_0 and Θ (so that θ remains constant)—are varied until a periodic path results.

What is the method used for the experimental investigation of the periodic paths? The principle is similar to that employed for the theoretical investigation. Even in this case the magnitude R_0 is varied, of course not so that the absolute difference in distance between the elementary magnet and the beginning point for the rays varies with otherwise constant conditions, but rather so that the orbit is displaced more and more by increasing the magnetic moment, that is, the "1" in the diagram (Fig. 9) is displaced more and more towards the outside. The variation of the angle of projection Θ is the second possible variation, by means of which direct adjustment of the corresponding periodic path can be effected (see Fig. 11, varying the angle of projection by turning the loop to the left). Naturally, no stress is placed on a definite value for γ as this is only a mathematical auxiliary. On the other hand, with the first group of tests, θ was maintained equal to 90°, just as in the theoretical investigation, that is, operations were effected with an electronic emission-center which could be swung round on an axis situated in the equatorial plane and passing through the elementary magnet.

Results—Theory and experiment led to the same results in as far as they concerned the same types of paths. Beyond this, however, the theory enables paths to be calculated which in view of their complicated nature are no longer applicable for experimental research. On the other hand, experiment has shown paths which have not yet been found mathematically. Let us first consider those paths which have been found both by theory and experiment.

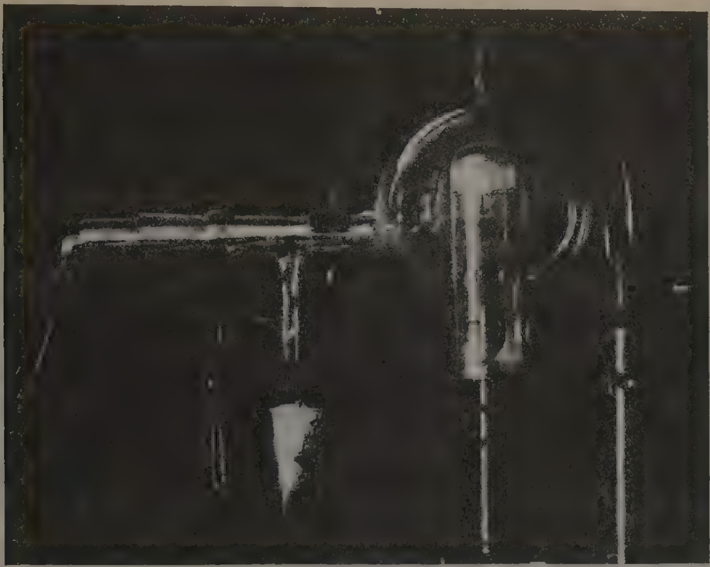


FIG. 11—Experimental apparatus for photographing a periodic path

Figure 12 depicts a periodic path of the most simple form. The path for which γ is equal to -0.8 has already been calculated by Störmer in 1906. Figure 13 reproduces a path of the same category characterised by the value $\gamma = -0.97$. The orbit for $\gamma = -1$, as reproduced in Figure 4, also belongs to this group. Finally, Figures 15 and 14 show the second path for $\gamma = -0.97$, as found in Figure 10, and a corresponding path for $\gamma = -0.8$.

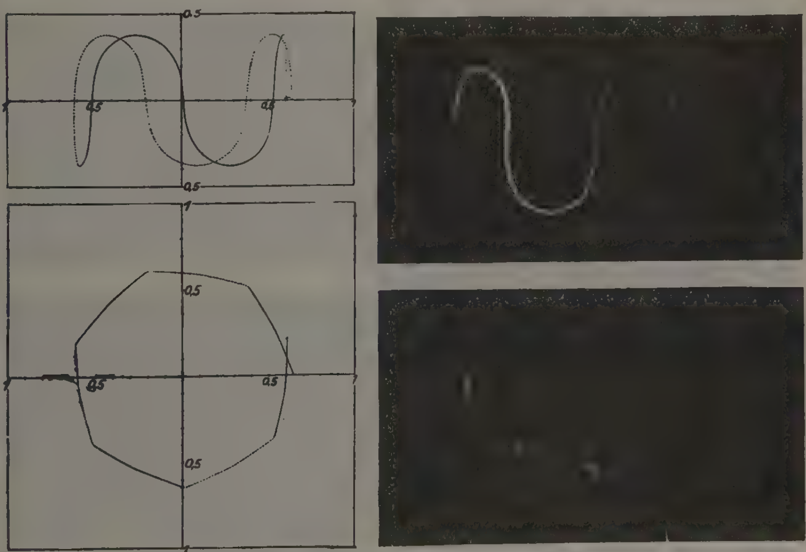


FIG. 12—Single pendulating paths for the theoretical case $\gamma = -0.8$ (at left) and experimental results

With respect to the illustrations of the experimental periodic paths, it may be mentioned that they are not quite identical with the theoretical paths because of slightly different initial conditions. Such differences,

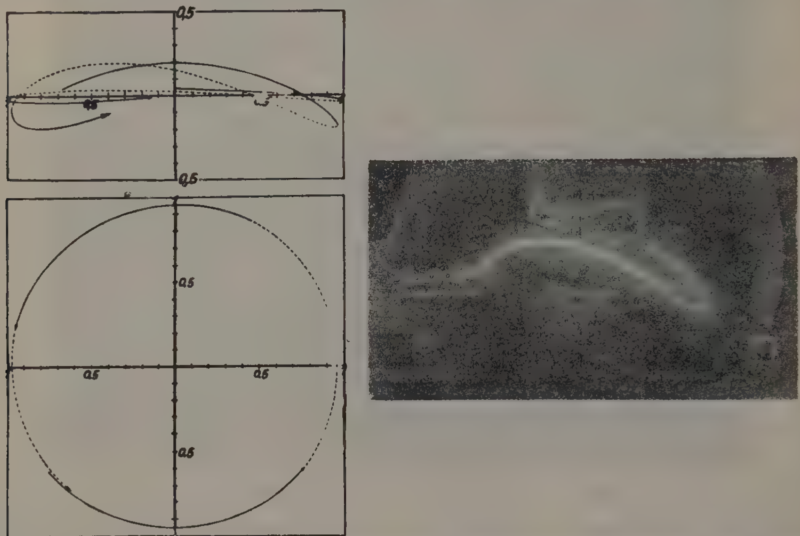


FIG. 13—Single pendulating periodic paths for the theoretical case $\gamma = -0.999$ (at left) and experimental results

nevertheless, are quite insignificant, and this remark also holds for the differences arising from the difficulty of photographing the phenomenon from exactly the same points of view as in the figures representing the theoretical orbits. For reproduction, it was necessary to retouch the

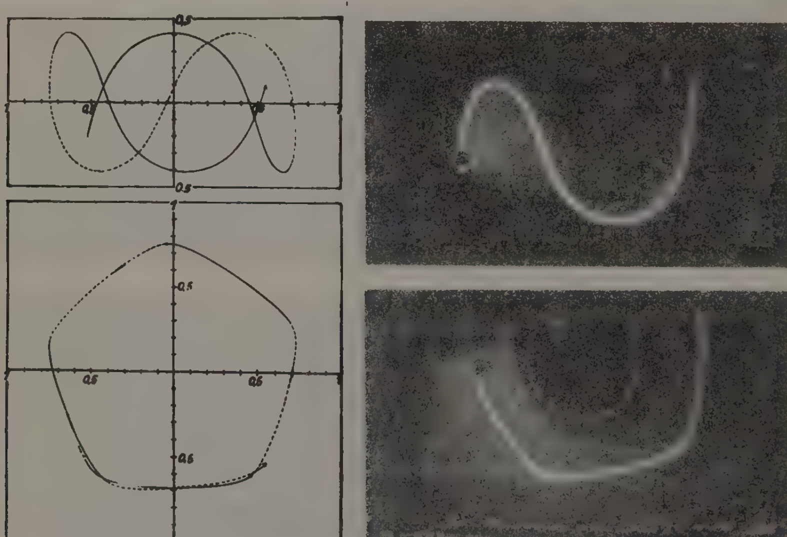


FIG. 14—Single pendulating periodic paths for theoretical case $\gamma = -0.8$ (at left) and experimental results

paths, especially those showing the lower figures, as the contrast between the paths and the luminous mass of diffuse electrons which surround the elementary magnet outside the boundary of the torus is insufficient in some places.

A more complicated periodic orbit which represents another type of path, is shown in Figure 16 in theory and experiment. The experimenter

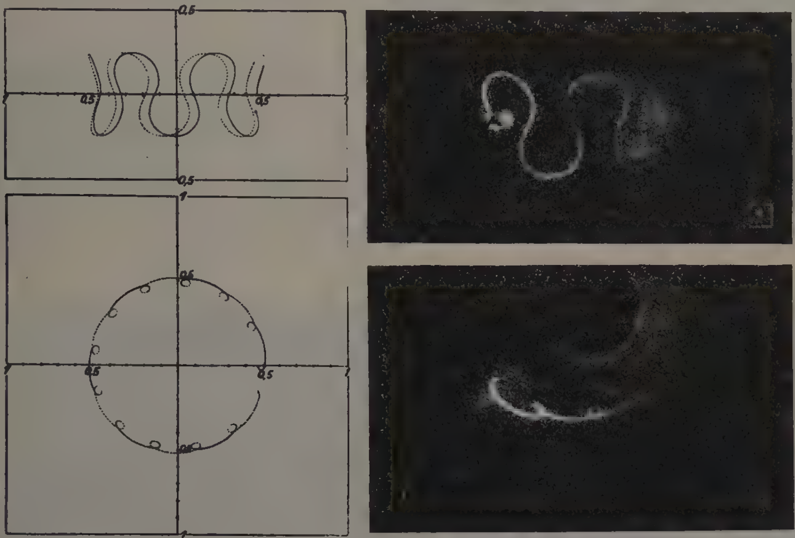


FIG. 15—Single pendulating periodic paths for theoretical case $\gamma = -0.97$ (at left) and experimental results

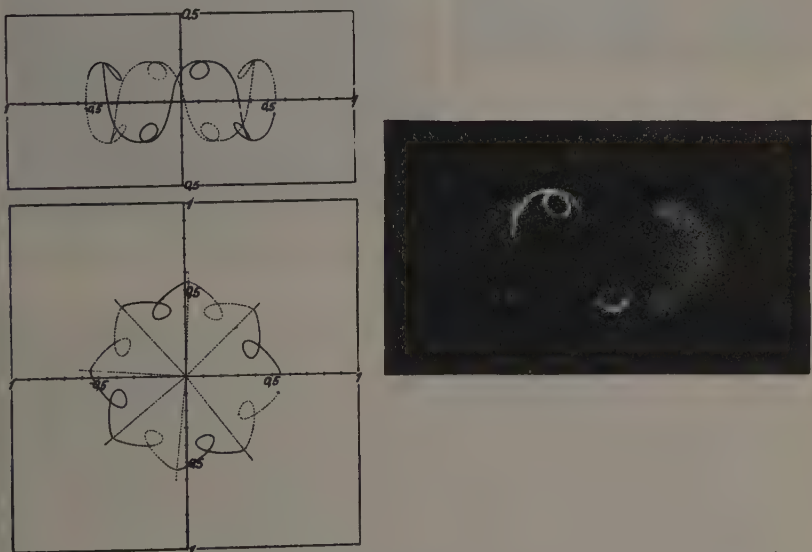


FIG. 16—Looping periodic paths for theoretical case $\gamma = -0.97$ (at left) and experimental results

here encounters certain difficulties as the electronic ray is liable to be split up when forming the narrow loops.

All the paths introduced up to the present belong to those periodic paths which are symmetrical about the equatorial plane and where each loop resembles the immediately preceding one. The periodic path which is depicted in Figure 17, and which is not symmetrical about the equatorial plane, is however, more complicated. Experimental reproduction was possible for this path although only a small section of it could be obtained. This remark also applies to Figure 18 and the succeeding figures; the theory is not referred to in any great detail in the present treatise.

In all of the paths which have been reproduced up to this point, the succeeding loop is always identical with the loop immediately preceding it. Experiment has nevertheless shown that paths exist with which such is not the case. Figures 19 and 20 give sketches of two such paths of a simple form; only small zones of this path have been photographed. The track of the path has been completed by drawing.

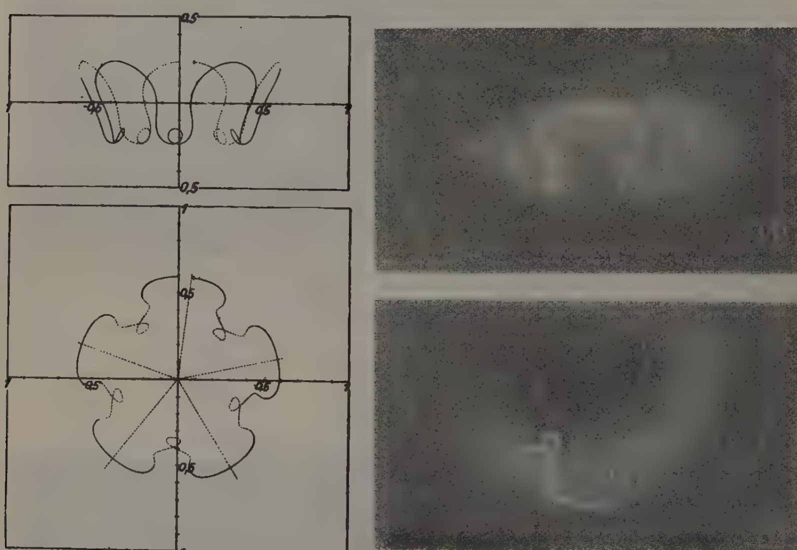


FIG. 17—Paths non-symmetrical to the equatorial plane for theoretical case $\gamma = -0.97$ (at left) and experimental results

The toroidal space—One of the difficulties of the aurora-polaris theory is that on our planet the phenomenon is also observed in temperate zones, whereas the theory suggests that, with a reasonable assumption for the velocity of the electronic ray, it is possible for this phenomenon to occur in the small region of 4° about the pole only. In other words, the theoretical electronic torus cuts the Earth's surface at a distance from the magnetic axis of only 4°, whereas actually the most frequent aurora-polaris phenomena occur at 20°. Störmer has pointed out that this difficulty is easily obviated if the action of a ring-current far away from the Earth is considered, this current flowing parallel to the magnetic equator. As theory and experiment have shown the possibility of periodic paths in

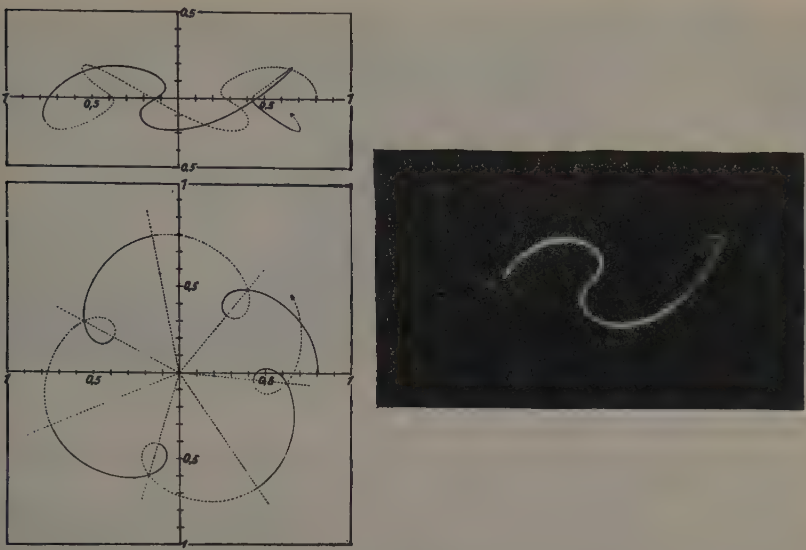
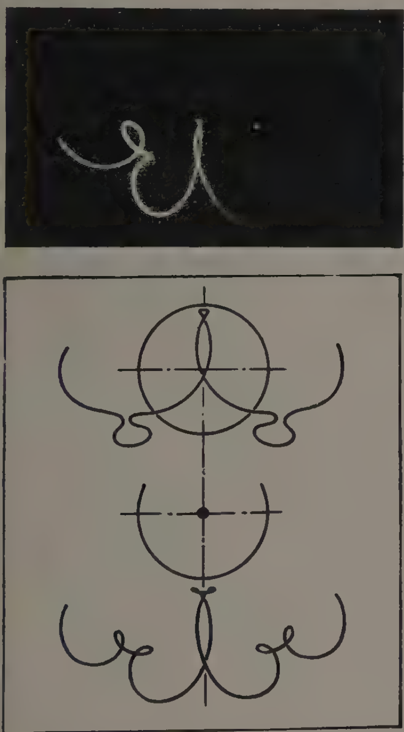
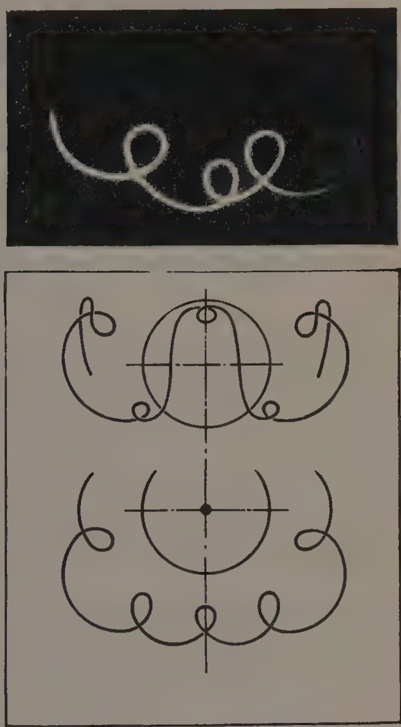


FIG. 18—Paths non-symmetrical to the equatorial plane for theoretical case $\gamma = -0.97$ (at left) and experimental results





FIGS. 19 and 20—Experimental results for computed complicated periodic paths

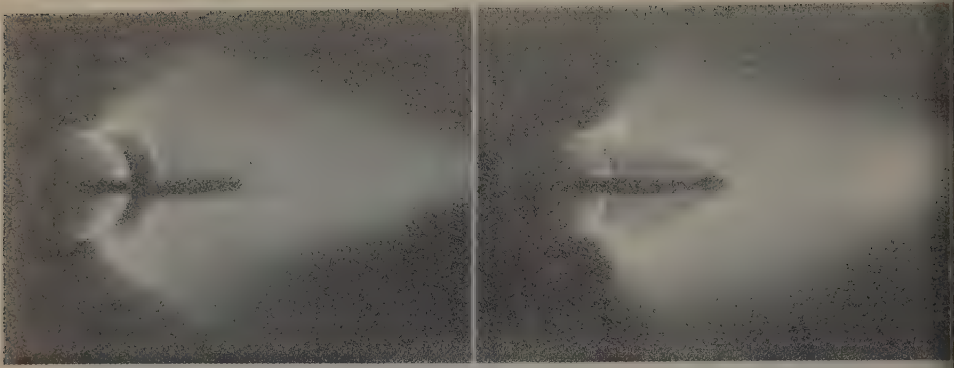


Fig. 21—Action of a ring-current on the electronic torus according to experiment

which the electrons finally travel in the same direction about the Earth, this theory seems now more firmly grounded.

The action of the ring-current on the electronic torus can also be demonstrated experimentally. This is shown by Figure 21, in which the torus has been photographed both with and without the ring-current. To obtain these results, the ring-current was produced by a circular conductor.

It is readily seen that a distortion of the electronic torus accompanies the switching on of the ring-current, and that the impact-zones of the aurora polaris are displaced towards the temperate zones.

Forschungs-Institut der AEG,
Berlin, December 1930

RÉVÉREND PÈRE STANISLAS CHEVALIER, S.J.[1]

Le Révérend Père Stanislas Chevalier naquit en Vendée, le 22 octobre 1852, et entra dans l'Ordre des Jésuites en 1871. Après ses propres études et quelques années d'enseignement, il demanda à être appliqué à la mission de Chine. Il y arriva en octobre 1883 et y travailla 47 ans, presque jour par jour, sans l'avoir jamais quittée.

Sauf quelques courtes interruptions, soit pour ses études ecclésiastiques, soit pour un peu de ministère apostolique, toute la carrière du Père Chevalier se passa à l'observatoire de Zi-ka-wei, et il fut pour beaucoup dans la réputation de cet établissement.

Il en fut nommé directeur en mars 1888, pour remplacer le Père Marc Dechevrens, que sa santé avait rappelé en Europe.

Outre la routine assez chargée de l'Observatoire météorologique et spécialement du département magnétique, dont il eut la conduite jusqu'en 1898, il donna de l'élan aux services de l'heure et des avertissements, déjà organisés par le Père Marc Dechevrens, mais encore trop restreints.

Son influence lui permit de fonder une société météorologique à Shanghai en 1892. Il faut avouer que l'activité des membres se borna à peu près à lire un rapport annuel du Père Chevalier, puis de son successeur. La société s'éteignit silencieusement vers 1898. Les cinq ou six rapports ont leur valeur; le Père Chevalier s'y applique surtout à l'étude des tempêtes dues à la mousson d'hiver, alors assez mal connue.

On lui doit aussi à cette date un mémoire fort travaillé sur les observations thermométriques, hygrométriques et actinométriques à Zi-ka-wei, de 1873 à 1892, d'autres sur la mousson, sur les orages, etc.

Remplacé à la tête de l'Observatoire par le Révérend Père Louis Froc, le Père Chevalier fit quelques tournées magnétiques dans les phares de la Côte, dans le bas Kiangsu, et un voyage de sept mois sur le Fleuve Bleu jusqu'au Szechwan. Il en rapporta un ample récit et un atlas en 64 très grandes planches, qui n'a pas été refait.

En même temps avec l'approbation de ses supérieurs, il avait l'initiative de faire construire par P. Gautier, de Paris, un grand équatorial double. Ce télescope fut en réalité installé en 1901, non à Zi-ka-wei, mais à Zô-sè, sur une colline isolée. Dès la même année le Père Chevalier devint directeur de ce nouvel observatoire, dont il fut la cheville ouvrière et dont il garda la conduite pendant 23 ans.

Il appliqua d'abord son bel instrument à l'étude du Soleil, un peu, il faut le dire, contre la pensée du constructeur. Nombre de mémoires sur des planètes, des comètes, des amas d'étoiles, sur la forme du Soleil et de la Lune, sur des positions photographiques d'étoiles tout le long de l'équateur, etc. montrent l'étendue de ses préocupations scientifiques. Le nombre de ces mémoires dépasse bien la trentaine. Les Annales de Zô-sè, presque entièrement de sa plume, ont actuellement 16 volumes.

Bien que son âge lui donnât droit à un peu de repos, il accepta en 1926 de reprendre la direction de l'Observatoire de Zi-ka-wei, en l'absence du Révérend Père Froc et de contribuer au travail mondial de la révision des longitudes, en octobre-novembre 1926.

Ce travail honorablement accompli, au retour du Révérend Père Froc, en février 1929, le Révérend Père Chevalier quitta l'Observatoire et donna le reste de ses forces à un emploi plus exclusivement apostolique et plus conforme à ce qu'il avait toujours eu à coeur. Il s'y épuisa et s'éteignit, le 27 octobre 1930, à Shanghai.

[1]The JOURNAL is indebted to Reverend J. de Moidrey, S. J., of the Zi-ka-wei Observatory for kindly supplying this biographical sketch as well as the photograph from which Plate I was made.

AMERICAN *URSI* BROADCASTS OF COSMIC DATA[1]

Summary American URSI daily broadcasts of cosmic data, November, 1930, to January, 1931

Day	November							December							January						
	Magnetism			Sun-spot		Solar constant		Magnetism			Sun-spot		Solar constant		Magnetism			Sun-spot		Solar constant	
	Char.	Type	G. M. T. begin. distur.	Groups	No.	Value	Char.	Char.	Type	G. M. T. begin. distur.	Groups	No.	Value	Char.	Char.	Type	G.M.T. begin. distur.	Groups	No.	Value	Char.
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1	0	..	.. ....	4	38	1.939	*f*	0	..	.. ....	3	15	1.945	*s*	0	..	.. ..	...	...	1.946	*f*
2	0	..	.. ....	5	28	......	..	0	..	.. ....	3	13	1.943	*s*	0	..	.. ..	...	...	......	..
3	0	..	.. ....	3	15	1.916	*u*	1	*i*	1 10	2	8	1.949	*s*	0	..	.. ..	...	...	1.922	*u*
4	1	*b*	10	2	4	1.912	*u*	2	*i*	.. ....	2	8	1.948	*f*	0	..	.. ..	2	4	1.941	*f*
5	0	..	.. ....	1	1	1.933	*u*	0	..	.. ....	2	3	1.942	*s*	0	..	.. ..	2	4	......	..
6	0	..	.. ....	1	1	1.941	*f*	0	..	.. ....	1	1	1.949	*f*	0	..	.. ..	...	...	......	..
7	0	..	.. ....	2	4	1.948	*f*	0	..	.. ....	1	1	1.948	*s*	0	..	.. ..	...	...	......	..
8	0	..	.. ....	1	4	1.933	*u*	0	..	.. ....	0	0	1.943	*f*	0	..	.. ..	...	...	......	..
9	1	*b*	9 50	1	1	1.938	*s*	0	..	.. ....	1	1	1.946	*f*	0	..	.. ..	...	...	......	..
10	0	..	.. ....	1	1	1.945	*f*	0	..	.. ....	1	10	1.941	*f*	1	*i*	.. ..	1	3	1.934	*u*
11	0	..	.. ....	1	1	1.941	*f*	0	..	.. ....	2	11	1.944	*f*	0	..	.. ..	1	3	1.943	*s*
12	0	..	.. ....	1	3	1.939	*f*	0	..	20	...	....	1.948	*s*	0	..	.. ..	2	5	......	..
13	0	..	19 30	...	....	1.942	*f*	1	*p*	.. ....	1	7	1.950	*s*	0	..	.. ..	3	10	1.927	*u*
14	1	*p*	.. ....	1	5	1.938	*s*	0	..	.. ....	2	17	1.953	*s*	0	..	.. ..	3	11	......	..
15	1	*i*	.. ....	1	4	1.942	*f*	0	..	.. ....	2	14	1.949	*s*	0	..	.. ..	4	13	1.939	*f*
16	0	..	.. ....	...	....	......	..	0	..	.. ....	2	8	1.951	*s*	1	*o*	.. ..	2	12	1.939	*f*
17	0	..	.. ....	...	....	1.943	*f*	0	..	.. ....	2	4	1.949	*s*	1	*i*	.. ..	3	11	1.942	*f*
18	0	..	.. ....	2	17	1.946	*s*	0	..	.. ....	4	15	1.946	*f*	1	*i*	.. ..	2	15	1.946	*f*
19	0	..	.. ....	2	10	1.949	*s*	0	..	.. ....	5	15	1.945	*f*	0	..	.. ..	2	6	1.945	*f*
20	0	..	.. ....	2	11	1.943	*s*	0	..	.. ....	5	7	1.942	*f*	0	..	.. ..	2	9	1.951	*f*
21	0	..	.. ....	4	14	1.944	*f*	1	*i*	.. ....	3	5	1.944	*f*	0	..	.. ..	2	10	......	..
22	0	..	.. ....	...	....	1.934	*f*	1	*p*	.. ....	3	10	1.946	*f*	0	..	.. ..	2	11	......	..
23	0	..	20 30	4	12	......	..	1	*i*	.. ....	6	20	1.941	*u*	0	..	.. ..	...	...	1.936	*u*
24	1	*i*	15	5	12	......	..	1	*i*	.. ....	...	....	1.956	*f*	0	..	.. ..	2	6	......	..
25	2	*i*	.. ....	4	8	......	..	0	..	.. ....	6	21	1.958	*f*	0	..	.. ..	...	...	1.922	*u*
26	1	*i*	.. ....	...	....	1.950	*f*	0	..	.. ....	6	20	1.949	*f*	1	*p*	.. ..	1	1	......	..
27	0	..	.. ....	...	....	1.953	*f*	0	..	.. ....	3	10	......	..	0	..	.. ..	...	...	......	..
28	0	..	.. ....	7	26	1.947	*f*	0	..	.. ....	...	....	......	..	0	..	.. ..	1	2	1.922	*u*
29	0	..	.. ....	6	32	1.939	*u*	0	..	.. ....	1	1	......	..	0	..	.. ..	...	...	......	..
30	0	..	.. ....	5	32	1.950	*s*	0	..	.. ....	2	2	......	..	0	..	.. ..	...	...	......	..
31	...	..	.. ....	...	....	......	..	0	..	.. ....	1	1	......		0	..	.. ..	...	...	......	..
Mean	0.3	..	.. ....	2.8	11.8	1.940	..	0.3	..	.. ....	2.6	8.9	1.947	..	0.2	..	.. ..	2.1	7.5	1.937	..

Greenwich mean time for endings of storms: 12^h, Nov. 4; $10^h\ 45^m$, Nov. 9; 8^h, Nov. 26; $14^h\ 30^m$ Dec. 4.

The first three columns of the Table give (1) the magnetic character according to the scale 0-2 of the International Commission of Terrestrial Magnetism and Electricity, (2) the type featuring the day other than normal by the letters *b*, *p*, *o*, and *i* for days marked by bay, rapid pulsations, long-period oscillations, and irregular oscillations, respectively, and (3) the hour and minute of Greenwich mean time marking the beginning of a storm, the end of the storm being indicated in the footnote to the Table. The next two columns give the data relating to sunspots: (1) the number of groups of spots and (2) the total number of spots. It is to be noted that sunspot-numbers such as those from Zürich can be obtained from the number of groups and spots given in the Table by the formula $N=k\ (10g+s)$, where k for Mount Wilson is about 0.77. The sixth and seventh columns show (1) the value in calories of the solar constant, and (2) by letters *s*, *f*, and *u* whether the determination was satisfactory, fair, or unsatisfactory, respectively.

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[1]For previous announcements see Terr. Mag., **35**, 184-185 and 252-253 (1930).

PROVISIONAL SOLAR AND MAGNETIC CHARACTER-FIGURES, MOUNT WILSON OBSERVATORY, OCTOBER TO DECEMBER, 1930[1]

During the last quarter of 1930 several magnetic storms of intensity 1.0 and two of intensity 1.5 were recorded at Mount Wilson.

On October 3, at $4^h\ 36^m$, G. M. T., a disturbance of intensity 1.0 began with an increase in the horizontal intensity. At $10^h\ 18^m$ of the same day the horizontal intensity again increased suddenly, but neither of these changes had the appearance of a typical "sudden commencement." An active spot-group which crossed the central meridian on October 2 was 11° west at the beginning of this storm.

On October 14 a moderate disturbance of intensity 1.0 began suddenly at $4^h\ 24^m$, G. M. T. It was probably due to the group of spots which was then 17° east of the central meridian. On October 17 when this group, which had steadily diminished since October 14, was about 35° west of the central meridian, a new active group began to develop immediately following it. This new group probably caused the magnetic disturbances of intensity 1.0 on October 17 and 20.

On October 25 at about 14^h, G. M. T., another moderate magnetic disturbance began to develop. A large active group of spots was then 41° east of the central meridian, and a new group was developing rapidly 26° west of the central meridian.

On November 13 a disturbance of intensity 1.0 commenced suddenly at $19^h\ 28^m$, G. M. T. A group of spots, 80° east, which had just been brought into view by the Sun's rotation was probably responsible for this disturbance.

On November 24 a magnetic storm of intensity 1.5 began at about 18^h, G. M. T. Five groups were visible, four of them moderately large. The most active of these was 31° east, another was exactly on the meridian, and the group which was 80° east on November 13 was then 75° west.

Another disturbance of intensity 1.5 began suddenly on December 3 at $1^h\ 07^m$. Two groups were then visible, the more active one was 10° west, the other 60° west of the central meridian.

On December 20 a disturbance of intensity 1.0 began at about 15^h, G. M. T. Five groups were then visible, none within 30° of the central meridian. The most active was 43° east. This was a return of the group which was 31° east at the beginning of the storm of November 24.

The number of groups of sunspots observed daily, given in these tables, may differ from those transmitted daily to *Science Service* for the broadcast of cosmic data, because the latter are telephoned from the Observatory as soon as the observations are made, while those given here are assigned after the spots have been classified and grouped according to their magnetic behavior.

[1]For previous tabulations from November 1929, see Terr. Mag., 35, 47-49, 92, and 249-251 (1930).

October, 1930

Day	K_2 A	K_2 B	$H\alpha B$ A	$H\alpha B$ B	$H\alpha D$ A	$H\alpha D$ B	No. groups	Mag'c char.
1	...	...	...	...	...	...	2	1.0
2	2	2	2	3	1	1	3[c]	0.5
3	1	2	2	2	2	2	2	1.0
4	1	1	2	2	2	1	4	1.0
5	2	1	2	1	2	1	4	0.5
6	2	1	2	1	2	1	4	0.5
7	2	1	2	1	1	1	3	0.0
8	...	...	...	...	...	...	...	0.5
9	...	...	...	...	...	...	...	0.0
10	...	...	...	...	...	...	...	0.0
11	2	3	...	...	...	...	2[d]	0.0
12	2	2	3	2.5	1	1	2	0.0
13	2	1	3	2	1	1	2	0.0
14	2	2	2.5	2	1	0	2	1.0
15	2	2	2	2	1	0	2	0.0
16	2	2	2	2	2	1	2	0.0
17	1	1	2	1	2	1	1	1.0
18	1	0	1	1	2	2	3	0.5
19	1	0	1	1	2	2	2	0.5
20	1	0	1	0	2	2	1	1.0
21	0	0	0	0	2	0	1	0.5
22	0	0	...	...	...	...	2	0.0
23	1	0	1	0	2	0	2	0.0
24	1	0	1	0	0	0	4	0.0
25	1	1	1.5	1	0	0	2	0.5
26	1.5	1	1.5	1	0	0	6	1.0
27	2	2	2	2	1	0	5	1.0
28	2	2.5	2	3	1	2	6[e]	1.0
29	2	3	2	3	2	2	5	1.0
30	2	2	2	3	2	2	4	1.0
31	2[a]	1	3[a]	2	1	1	6	0.5
Mean	1.5	1.2	1.8	1.5	1.4	1.0	3.0	0.5

November, 1930

Day	K_2 A	K_2 B	$H\alpha B$ A	$H\alpha B$ B	$H\alpha D$ A	$H\alpha D$ B	No. groups	Mag'c char.
1	2	1	2	1	1	1	5	0.5
2	2	0	2	0	1	0	5	0.0
3	2	0	1	0	1	0	4	0.0
4	1	1	1	1	1	1	2	1.0
5	1.5	2	2	2	2	2	1	0.0
6	2	2	2	3	2	2	1	0.0
7	2	3	2	3	2	2	1	0.0
8	2	2	2	2	2	2	1	0.5
9	2	2	...	...	...	...	1	1.0
10	2	1.5	2	2	2	1	1	0.5
11	1	1	1.5	1	2	1	1	0.0
12	1	1	1	1	2	1	1	0.0
13	1	0	...	...	...	...	...	0.5
14	...	...	...	...	...	...	1	1.0
15	1	0	1	0	2	1	1	1.0
16	...	...	...	...	...	...	...	0.5
17	...	...	...	...	...	...	...	0.0
18	1	2	1	2	1.5	1	2	0.0
19	2	2	2	2	2	1	2[f]	0.0
20	2	2	2	2	1	0	2	0.0
21	2	1	2	1	1	0	4	0.0
22	...	...	...	...	...	...	...	0.0
23	2	2	2.5	2.5	1	1	4	0.5
24	2	2.5	3	3	2	2	5	1.5
25	2.5	4	3	4	2	2	5	1.5
26	...	...	...	...	...	...	7	1.0
27	...	...	...	...	...	...	7	1.0
28	2.5	3	3	3	2	1	7	1.0
29	2.5	2	2.5	2	2	0	6	0.5
30	2	2	2.5	2	1	1	6	1.0
31	...	...	...	...	...	...	...	...
Mean	1.8	1.6	2.0	1.8	1.6	1.0	3.2	0.5

December, 1930

Day	K_2 A	K_2 B	$H\alpha B$ A	$H\alpha B$ B	$H\alpha D$ A	$H\alpha D$ B	No. groups	Mag'c char.
1	2	2	2	2	2	2	4	0.0
2	1.5	1.5	1.5	2	2	2	3	0.0
3	1	1.5	1	1.5	1	2	2	1.5
4	1	1	1	1	2	2	2	1.5
5	1	1	1	1	2.5	2	1	0.0
6	1	0.5	1	1	2.5	2.5	1	0.0
7	0	0	0	0	2	1	1	0.0
8	0	0	...	...	...	...	0	0.0
9	0	0	0	0	2	1	1	0.0
10	1	0	1	0	2	1	3	0.0
11	1	0	1	0	1	1	4	0.0
12	1	0	2[b]	0	1.5	1	4	0.5
13	1	1	2	1	2	1	1	0.5
14	1	2	2	2	2	1	3	0.5
15	2	2	2	2	1.5	2	2	0.5
16	2	2	2	2	1	1	2	0.0
17	2	1	...	...	...	...	4	0.0
18	2	1	2	1	1	1	5	0.0
19	2	1.5	2	2	1	0	7	0.5
20	2	2	...	...	...	...	5	0.5
21	...	...	...	...	...	...	3	1.0
22	2.5	3	2	3	1	1	4	0.5
23	...	...	...	...	...	...	6	1.0
24	...	...	...	...	...	...	...	1.0
25	2.5	3	2	2	2	2	6	0.5
26	...	...	...	...	...	...	6	0.5
27	2	2	2	1.5	2	1	3	0.5
28	2	1	2	1.5	2	1	1	0.0
29	1	1.5	...	...	...	...	1	0.5
30	1	1	2	2	2	1	2	0.0
31	1	1	1	1	1	2	1	0.0
Mean	1.4	1.2	1.5	1.3	1.7	1.4	2.9	0.4

[a]Small area very bright K_2 large group. Very bright $H\alpha$ same group. [b]Very bright $H\alpha$ East group. [c]Active group 10° south of center of disc. [d]Large group near center. [e]Large group 11° south of center. [f]Active group near center.

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PROVISIONAL SUNSPOT-NUMBERS FOR DECEMBER, 1930, TO FEBRUARY, 1931

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	Dec.	Jan.	Feb.	Day	Dec.	Jan.	Feb.
1	47[a]	0	0	17	30[d]	*E*..[c]	..
2	36	7	8	18	52[d]	22	45
3	35	0	28[d]	19	*W*50[cc]	..	..
4	21	..[d]	..	20	42	25[a]	..[ab]
5	8	18	25	21	35[c]	24	96
6	8	11	29	22	28	22	..
7	7	11	19	23	31[a]	21	100
8	..	12	27[a]	24	45	..	92
9	*E* 8[c]	14	29	25	52[a]	20	68[a]
10	19	11[a]	28	26	53	..	82[d]
11	21	10	20	27	41	8	72
12	..	9	*E*20[c]	28	26	0	47
13	15	*M*16[c]	23	29	9	7	
14	22	41	*E*19[cd]	30	15	0	
15	22[a]	43	41	31	14	..	
16	20	27	44				
				Means	28.0	15.2	41.8
				No. days	29	25	23

Mean for the quarter October to December, 1930: 32.3 (84 days)
Mean for year 1930: 38.9 (337 days)

*a*Passage of an average-sized group through the central meridian.
*b*Passage of a larger group through the central meridian.
*c*New formation of a large or average-sized center of activity: *E*, on the eastern part of the Sun's disc; *W*, on the western part; *M*, in the central zone.
*d*Entrance of a large or average-sized center of activity on the east limb.

Zürich, Switzerland W. BRUNNER

NOTES ON AURORA AUSTRALIS

In looking through some of our rainfall records recently, I extracted the following notes regarding aurorae. They are not exhaustive, but may be of interest.

Station	Lat. South °	Lat. South ′	Long. East °	Long. East ′	Aurora seen Day	Aurora seen Month	Aurora seen Year	Remarks
Otiake	44	48	170	32	29	4	1927	
					4	5	1927	
					21	7	1927	
					22	10	1927	
					10	11	1928	
					17	2	1929	
					12	3	1929	
Robin Hood Bay	41	23	174	04	17	6	1915	Splendid aurora
Awarua	46	32	168	21	4	9	1917	Brilliant (9 p. m.)
					15	4	1926	Brilliant (7 p. m.)
Tahakopa	46	31	169	25	15	4	1926	Magnificent display, evening
					10	3	1929	
					12	3	1929	
Turua	37	14	175	31	15	5	1921	
Bulls	40	11	175	21	17	6	1915	
					9	8	1917	
					15	5	1921	6:30-8 p. m. strong
Opunake	39	27	173	52	17	6	1915	
					15	5	1921	Brilliant colored
Wellington	41	16	174	46	20	12	1918	
					23	4	1921	
					15	5	1921	Brilliant aurora
					15	4	1926	
					10	3	1929	
					13	3	1929	Brilliant aurora

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SOME NOTES REGARDING AURORAL DISPLAYS DURING THE MONTHS OF AUGUST AND SEPTEMBER, 1930

A number of communications have been received from various sources giving detailed descriptions of auroral displays observed at points in the United States and Canada during the months of August and September, 1930. As these notes may contain material of interest to readers of the JOURNAL, they are presented below in somewhat condensed form.

Aurora of August 6, 1930—The following report by L. E. Cunningham and E. M. Lindsay, describes the aurora as observed at the Harvard College Observatory:

"About 1^h 50^m on August 6, we observed a band, resembling a searchlight, that would be described as "very conspicuous," stretching, roughly, from east of Pegasus to west of Hercules, due *east and west.* It was brightest at the center and rather tapering at the ends. The sky was somewhat hazy around the horizon, and wispy clouds were about. The clouds were moving south to north, the band slowly but decidedly drifting *southward.* At the center of the band stars were somewhat dimmed but visible. The band was watched for some ten minutes, though noticed about ten minutes earlier by F. Bowie. His first impression (as was that of Mr. Lindsay) was that of a searchlight. The band grew dimmer, until only a streak finally persisted in Hercules, and then it too disappeared. The most conspicuous things were: (1) Its position —a great circle due east and west; (2) its very sharply defined outline; (3) its brilliancy; (4) its persistence; (5) its motion contrary to the clouds present and its presenting a spectacle which seemed entirely unlike a cloud formation. There was some evidence of flickering. . . ." [Note appended by Dr. W. J. Fisher: "Mr. Lindsay told me the band was probably 3 degrees in width, comparing with pointers."]

Aurora of August 18, 1930—R. J. Starr, of Briercrest, Sask., Canada, reports that at 23^h 40^m he observed an aurora in the form of a field of pale light extending from north-northwest to east and about 50° above the horizon. The light seemed at first to be pulsating, but, upon careful observation, it was found that dark shadows of various shapes were passing over the field of light. One of these swiftly passing shadows appeared like a perpendicular wave of darkness, one or two degrees wide, extending as high as the field; others looked like dark rays, quickly vanishing. In short, there were shapes similar to northern lights and similar motions, but darkness instead of light. The rising Moon obscured the display so that careful observation was necessary. At 1^h 25^m the field of pale light could still be seen with occasional shadows passing rapidly across it.

Aurora of August 21, 1930—The following extracts from a report by Dr. J. L. Dunham describes the aurora of August 21, 1930, as observed by him at a point about one-half mile southwest of the northern end of Caspian Lake, at Greensboro, Vermont (approximately in latitude 44° 36′ north and longitude 72° 20′ west).

"On the evening of Thursday, August 21, about 21^h 55^m I saw a narrow arc of light straight across the sky from east to west almost from one horizon to the other, and going near the zenith. In the west it went just south of Arcturus (about ½° south), then through the southern

end of Corona Borealis, just south of Vega (the northern edge of the band just touching the star), and then down to the eastern horizon, going slightly north of the southermost star in the square of Pegasus. The band of light was between $\frac{3}{4}°$ and 1° wide, with sharp edges most of the way and was bright enough to obscure all but the brightest stars behind it. It did not appear colored, as a rainbow, but was uniform bluish white, just like ordinary northern lights. In the course of fifteen minutes it moved somewhat south. Then all of it except a small segment overhead moved slightly north again, leaving a bow, the bowed part of which lay practically on the zenith. At $22^h\ 12^m$ the sky was covered with clouds. At $22^h\ 45^m$ the sky was clear, but the arc had disappeared. All the evening there was a large general glow in the northern part of the sky and by 23^h an ordinary aurora, with shafts of light radiating up into the sky, was faintly visible.

"The position of the arc was such as to make it appear to be a rainbow, refracted from the upper atmosphere from a source of light at the north. However, the bow which appeared in it and the fact that it curved slightly north near the western horizon, do not seem compatible with this theory."

The phenomenon described above was also observed by Mrs. J. M. Clute, at her summer home at Amhurst Island, Canada. In a letter published in the *New York Times* of August 31, 1930, she states that: "An arch about the size of a rainbow was stretched across the sky from east to west, as white as the Milky Way, and the stars were as bright as could be. It was the strangest and most wonderful sight any of us had ever seen."

Aurora of August 30, 1930—We are again indebted to Dr. J. L. Dunham for the following description of this aurora, observed from the same position near Greensboro, Vermont, referred to above.

"This time the display consisted of two practically straight streamers across the southern sky, which did not change their position, but gradually appeared and then gradually faded again. One band ran from Capricornus in the southwest through northern Sagittarius in the south to somewhere in Ophiunchus, which was in the southeast. The streamer was *not*, however, symmetrical to the meridian. The other band rose halfway between Altair and Sagittarius and ran to a point about 3° below Arcturus, then pretty well in the western sky. In places the bands were diffuse and fairly broad, and in others they were quite sharp and narrow. The intensity shifted a lot and also the sharpness and as they faded they became sharper. The second band lasted longer than the first.

"I first noticed them at about $20^h\ 40^m$, and the display was ended by $21^h\ 10^m$. There was a half Moon near Antares and there were no ordinary northern lights visible. It was a warm and very clear night, after a warm and somewhat cloudy day. As far as I could see, the bands were not symmetrically placed with respect to the meridian nor the Moon or anything. They were greenish white like ordinary northern lights, and in every way looked like the arch seen on August 21, 1930, except for their position. They were both in the sky together."

Aurora of September 2-3, 1930—The following description has been compiled from the radio-reception log, kindly furnished by R. J. Starr, of Briercrest, Sask., Canada.

At $21^h\ 20^m$ a very pale arch was observed extending from the northwest to the east about 35° above the horizon at the center, from which a brush of faint rays pointed toward the zenith. Soon several of such brushes were formed as the arch grew fainter. The arch gradually rose until at $22^h\ 33^m$ it had reached the zenith. Seven minutes later this arch had vanished, but another pale one had formed, stretching across the sky from northwest to east at a height of 25° and 30°, while in the north-northwest there was seen a patch of strong light 10° high and above it a broken arch 10° long. At $23^h\ 00^m$ there was one small arch of strong light centered in the north-northwest. At $23^h\ 38^m$ the large arch reappeared, now passing 10° south of the zenith, but paler, while the small arch in the north-northwest was now irregular in shape and of very strong light of greenish tint. Other arches and segments now rapidly formed and disappeared, until by $0^h\ 24^m$ there was such a confusion of arches, patches, and rays extending from northwest to east, as to baffle description. One phase of particular interest was an irregular horizontal band, 8° and 10° high between north and northeast, which was deep red, slowly changing to pink at the lower edge. On the right half of the band, above the red, pale green was displayed, gradually shading into dark green. This display lasted less than a minute, but the colors were intense and brilliant. By $1^h\ 00^m$ the aurora had subsided into an arch of diffused light, 8° and 15° high, spanning the sky from northwest by north-northwest to east-northeast, increasing in light as well as width towards the left end, which grew stronger with a shifting and moving curtain only a few degrees in depth at the lower edge. The aurora was gradually fading away at $1^h\ 45^m$. Nothing of particular interest in radio reception was noted.

Aurora of September 18, 1930—Douglas F. Manning reports that he observed, at Alexandria Bay, New York, on the night of September 18, between $19^h\ 10^m$ and midnight, a very brilliant and active auroral display, particularly between $19^h\ 20^m$ and $21^h\ 45^m$, after which time it assumed the character of pulsating patches of green light over the greater part of the northern sky. At the beginning it assumed the form of thin pencils of intense green light, increasing in size and height, showing purple, red, light yellow, and indigo blue. There were a few strato-cumulus clouds in the sky, and it was clearly seen that the aurora was occurring far above them. Occasionally the patches of light were very intense, at which times the different colors appeared. Radio reception was good during the display.

Aurora of September 29-30, 1930—We are also under obligation to R. J. Starr, of Briercrest, Sask., Canada, for the following information regarding this aurora, which has been abstracted from his radio-reception log:

A patch of rays which soon disappeared was noticed at $18^h\ 02^m$. This was followed at $18^h\ 50^m$ by a patch of diffused light in the northeast. The aurora proper began about $19^h\ 30^m$ with an arch of diffused light reaching from the horizon to an altitude of 10° and stretching from north-northwest to east-northeast, and which at $20^h\ 00^m$ appeared as a broken arch in the north-northwest rapidly changing shape. Then ensued a series of confused streaks, arches, and patches of rays streaming up towards the zenith and quickly vanishing, only to be replaced by others. A shadow, presumably a cloud, occupied all the space from 15° east of north to east. At $21^h\ 05^m$ there suddenly appeared a cap

of milling rays, tinted with red, forming, about the zenith as center, three-fourths of a circle having an average radius of 10°. In ten minutes all this had vanished and pale diffused light had taken its place, with a single patch of rays 45° and 60° high in the northern sky. By $21^h\ 30^m$ there remained only pale diffused light stretching from north-northwest to south-southeast and extending south of the zenith, but soon an irregularly shaped arch was formed extending from northwest to east-southeast, with rays moving from one side to the other, the lower edge being faintly red. The shadow-cloud which only a few moments before had been lighted up was at $22^h\ 10^m$ transformed into a solid bank, forming roughly an arch from north-northwest to east, 40° high at its center, with rays showing over its upper edge at one point. At $22^h\ 50^m$ the display consisted chiefly of diffused light, patches of rays, and formations of many shapes, mostly overhead, extending from 30° above the northern horizon to 20° south of the zenith. The changes in shape were very rapid. Waves of light were observed to pass swiftly from the north across the zenith to within 45° of the southern and southwestern horizon, lighting up the sky with flickering and flaming patches wherever they passed. At $0^h\ 20^m$ the flickering still persisted, but a new formation was taking shape in the likeness of a square arch, one foot of which was 5° west of north and 20° above the horizon and the other 20° above the horizon in the east, the center reaching a height of 50° above the northern horizon. The whole formation flickered and flamed in a fantastic manner, but under the arch all was quiet, with a few areas of fairly steady light above the northern horizon. At $1^h\ 00^m$ the display covered, in large and small patches, the whole heavens, except for 30° above the southern and southwestern horizon, but the flickering had died down slightly. The state of rapidly changing and flickering forms persisted with little variation until about $3^h\ 35^m$, when an arch of moderately strong diffused light spanning the heavens from northwest to east-northeast was observed, and a little later a smaller one appeared 4° and 5° high, extending from north-northwest to north-northeast, with ends slightly more than 2° above the horizon. Above the larger arch a series of phantom light-patches, flitting and flashing here and there, rapidly appeared and disappeared. This form of display, with minor variations, lasted until $5^h\ 00^m$, when it either disappeared or faded in the morning light.

This display was accompanied by a great disturbance in radio reception and erratic behavior of the magnetic needle.

DEPARTMENT OF TERRESTRIAL MAGNETISM, H. D. HARRADON
CARNEGIE INSTITUTION OF WASHINGTON,
Washington, D. C.

NOTES ON GREEN FLASH OBSERVED AUGUST 29, 1928, AND OCTOBER 16, 1929

The following notes on the "green flash" seen on two occasions by members of the Byrd Antarctic Expedition may be of interest. The first occasion was at sea off the Florida coast on the evening of August 29, 1928. The green flash was seen at the end of a very smoky dull-red sunset. The disappearing tip of the Sun's disc showed red changing through yellow to green, the change taking place during the last two seconds before the Sun disappeared. The weather was fine, with about 3/10 strato-cumulus clouds circling the horizon at a fairly high altitude.

The second occasion was at the Bay of Whales, Antarctica, on October 16, 1929, just after 10 p. m. (165° west meridian time). At this time of year the Sun sets slowly, its path making only a small angle with the southern horizon. The green flash was seen many times during a period of one-half hour, by several members of the Expedition, including W. C. Haines, the meteorologist, and the writer. The green color lasted for about a second at a time. It could not be seen continuously with the head in a fixed position, but by moving the head red, yellow, and green colors could be seen, sometimes simultaneously from adjacent notches in the horizon illuminated by the Sun. The Barrier surface to the south, in which direction the effect was seen, was smooth as seen in ordinary light, but against the Sun's disc the unevenness caused by sastrugi (ridges several inches high) could be seen quite clearly. This allowed small sections of the Sun's disc to be seen, these sometimes showing red, yellow, or green.

When the Sun sank too low to be seen from the ground, it still was visible from the radio towers, and the above effect was seen at intervals for as long as one-half hour after the first observation. This was the only time the green flash was seen at Little America. There was a moderate southerly breeze and the temperature was less than $-20°$ *F*. Between the south horizon and our camp lay a hollow, in which the air was often cooler and less disturbed than the layers above. The fact that the phenomenon was seen at intervals of a second under what must have been favorable conditions indicates that a very critical state of the atmosphere is necessary as well as almost a point-source of light.

During the period of observation the phenomenon of "looming" (Barrier surface seemingly raised along the horizon) was seen at intervals.

DEPARTMENT OF TERRESTRIAL MAGNETISM, F. T. DAVIES
CARNEGIE INSTITUTION OF WASHINGTON,
Washington, D. C., October 22, 1930

PRINCIPAL MAGNETIC STORMS

ABINGER OBSERVATORY

DECEMBER 3-4, 1930

The following account, taken from *Nature* (December 13, 1930), of the magnetic storm of December 3-4, 1930, will be of interest to the readers of the JOURNAL: "A considerable magnetic disturbance, falling into the category of a small storm, occurred on December 3-4. The storm began with a characteristic 'sudden commencement' on December 3 at $1^h\ 15^m$, but apart from this the oscillations of the needles were not appreciable until about thirteen hours later, the most disturbed part of the traces being between 15^h and 22^h on December 3. The range in declination at Greenwich was 51′. At the time of the storm there was only a smallish sunspot, of area 130 millionths of the Sun's hemisphere, a little way past the central meridian. Spectroscopic observations, which greatly increase the range of detection and scrutiny of solar eruptions, were impossible, owing to fog or overcast skies. The recent magnetic storm appears to be the largest since that of March 11-13, 1929, though during 1930 a number of disturbances of somewhat lesser intensity have occurred."

Sitka Magnetic Observatory
October to December, 1930[1]

(Latitude 57° 03′.0 N.; longitude, 135° 20′.1, or 9^{h} $01^{m}.3$ W. of Gr.)

Greenwich mean time						Range		
Beginning			Ending			Decl'n	Hor. int.	Ver. int.
1930	*h*	*m*	*d*	*h*	*m*	′	γ	γ
Oct. 1	5	24	1	21	..	36.0	386	466
Oct. 17	3	42	18	02	..	195.7*	792*	700*
Oct. 26	2	..	31	02	..	121.6	1023	905**
Nov. 4	2	13	4	15	..	123.5	656	445
Nov. 24	3	..	26	02	..	102.6	717	636
Dec. 3	1	08	4	16	..	212.8	1079*	985**
Dec. 20	16	22	21	24	..	88.9	542	428

*Curve went off the paper in one direction.
**Curve went off the paper in both directions.

October 17-18, 1930—Although this storm was relatively short, it as active for most of its duration. There was a little sudden jog in ne curves at the point of beginning and for several hours there was ractically no activity. At 18^{d} 6^{h} the curves began the large slow scillations which lasted until 10^{h}, when the oscillations became rapid. rom 18^{d} 13^{h} to 18^{h} the motion of the curves was so rapid that they now up mostly as spots. However, the curves can be followed quite efinitely except at times during the latter part of this period. For a orm of this intensity, the *H*-maximum usually goes very high at the eginning of the storm. In this storm, however, the *H*-maximum, though occurring at the beginning of the storm, did not go much bove the normal value. Hence, the range in *H* was relatively small.

October 26-31, 1930—Although the ranges are rather large, on the hole, this was not a large storm. There are several active parts the eriods between which are only moderately disturbed. The most active arts are from 26^{d} 8^{h} to 26^{d} 24^{h} (the last half of this period being short, apid oscillations), 27^{d} 9^{h} to 16^{h} and 29^{d} 8^{h} to 13^{h}.

November 24-26, 1930—This was not a large storm. Small, rapid scillations extended almost through the entire period. The most active art was from 25^{d} 8^{h} to 22^{h}. During this period the oscillations were rge and fast and the three curves were grouped right together so that ney were crossing one another very frequently. However, the curves an be definitely followed at all times.

December 3-4, 1930—This was the most important storm of the uarter. At the time of beginning there were small sharp jogs in all of e curves. There was practically no activity until 3^{d} 8^{h}, when large scillations began, which lasted until 11^{h}. From this time until 18^{h} nese were very large and fast. From 13^{h} 30^{m} to 15^{h} 30^{m} the *H*-reserve

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

spot was off the bottom of the paper most of the time and the *D*-curve swung back and forth across the paper rapidly. These were probably some of the most rapid and largest *D*-oscillations ever recorded here. During this period the *Z*-curve swung on and off the gram very rapidly and the curves can be definitely traced only with greatest difficulty. From $3^d\ 22^h$ to $4^d\ 1^h$ there was a period of only slight activity. From the latter time to the end of the storm there were fast oscillations most of the time and some were rather large. The storm ends abruptly and is followed by normal curves almost entirely undisturbed.

FRANKLIN P. ULRICH, *Observer-in-Charge*

CHELTENHAM MAGNETIC OBSERVATORY
OCTOBER TO DECEMBER, 1930[1]

(*Latitude 38° 44'.0 N.; longitude 76° 50'.5 or $5^h\ 07^m.4$ W. of Gr.*)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Ver. int.
1930	*h m*	*d h m*	′	γ	γ
Oct. 17	5 30	18 05 ..	47.2	159	325
Nov. 25	0 ..	26 02 ..	46.6	163	102
Dec. 3	1 06	3 13 ..	43.1	199	170

GEO. HARTNELL, *Observer-in-Charge*

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

HUANCAYO MAGNETIC OBSERVATORY
OCTOBER TO DECEMBER, 1930

(*Latitude 12° 02'.7 S.; longitude 75° 20'.4 or $5^h\ 01^m$ W. of Gr.*)

October 17, 1930—As a large part of the magnetogram is missing because of failure of light, it is not possible to report on the disturbance of this date.

October 25, 1930—There was a sharp decrease in horizontal intensity of 165γ in five minutes of time, beginning at $16^h\ 09^m$.

November 13, 1930—Beginning at $19^h\ 27^m$ there was a short, rapid increase in horizontal intensity of 20γ, followed immediately by a sharp, rapid increase of 90γ, all taking place within five minutes. There was, however, no disturbance following.

December 3-4, 1930—At $1^h\ 07^m$ on December 3, 1930, a severe magnetic storm began with a sharp increase in horizontal intensity of 51γ and a slight shift in declination and vertical intensity. The early part of the storm showed only a slight disturbance, but from about 12^h the disturbance became very severe in the horizontal intensity with such large and rapid changes that there was some difficulty in tracing the path of the spot and the reserve spot on the trace; the declination and vertical intensity were also immoderately disturbed for this Observatory. This severe phase of the storm broke at about 21^h, but the horizontal-intensity trace remained exceptionally low until after 10^h on December 4.

All times given are Greenwich Civil Mean Time.

PAUL G. LEDIG, *Observer-in-Charge*

WATHEROO MAGNETIC OBSERVATORY

JANUARY TO AUGUST, 1930

(*Latitude 30° 19′.1 S.; longitude, 115° 52′.6 or 7h 43m.5 E. of Gr.*)

Greenwich mean time				Range		
Beginning		Ending		Decl'n	Hor. int.	Ver. int.
1930	h m	d h m		′	γ	γ
Feb. 12	3 04	14 21 ..		25	146	130
Mar. 11	19 32	16 (?) ..		32	170	230
May 4	23 50	6 16 ..		22	175	104
June 16	4 20	16 15 ..		31	203	246
Aug. 6	3 54	8 15 ..		26	88	185

February 12-14, 1930—This storm commenced February 12 with long-period variations of moderate amplitude lasting until 22^h. Then followed small fluctuations of short period until 8^h on February 13. They were succeeded by long-period variations of large amplitude ending at 21^h. The next period, ending at 13^h on February 14, was characterized by small, rapid fluctuations. There were a few large peaks and bays in the final interval ending at 21^h.

Magnetically disturbed conditions continued from February 15 to 18, with small fluctuations in the forenoon and larger variations in the afternoon.

March 11-16, 1930—Only small departures occurred in the first seven hours. There followed small rapid fluctuations superimposed upon a steady downward trend in horizontal intensity with large peaks and bays in all the elements. The storm did not end abruptly, and disturbed conditions existed until March 16, though in lesser degree.

May 4-6, 1930—The chief characteristic of this storm, which commenced about 23^h 50^m on May 4 and continued through May 5 and 6, was a decrease in the mean horizontal intensity of about 70γ between 5^h and 13^h, May 5. It was succeeded by a period of decreasing activity.

June 16, 1930—This storm had a period of slight disturbance lasting until 8^h, followed by large and rapid fluctuations in all the elements until 13^h, when there was a rapid recovery toward normal conditions which were reached at 15^h.

August 6-8, 1930—This moderate storm lasted about two and one-half days and was characterized throughout by bays and peaks in all three elements at irregular intervals. The *H*-trace exhibits more bays than either the *D*- or *Z*-trace with the most active periods from 8^h to 16^h on August 6, and from 5^h to 12^h on August 7. The peaks on the *Z*-trace arrived at later times than those in the *H*-trace by about 5 to 10 minutes.

F. W. WOOD, *Acting Observer-in-Charge*, and
W. C. PARKINSON, *Observer-in-Charge*

NIPPOLDT, A.: *Verwertung magnetischer Messungen zur Mutung für Geologen und Bergingenieure.* Berlin, Verlag von Julius Springer, 1930 (v+74 mit 19 Abb. und 36 Taf.). 24 cm.

The present manual is intended for the practical use of mining engineers and geologists in drawing conclusions regarding the underlying structure and disturbing bodies in the Earth's crust from magnetic measurements made on the surface. It is concerned only with the technique of interpretation and not with instruments nor directions for making the observations themselves. Throughout that author has striven to be practical, even the language used having been chosen with a view to rendering the subject readily intelligible to non-German readers, by whom, it is assumed, the book will be largely used.

The essential part of the work consists in tables and curves which have been worked out for selected typical cases, the two elements used being the vertical (Z) and the horizontal (H) intensities. With these typical cases, the magnetic observations taken on the surface may be compared in order to find the corresponding profile and thus to obtain information regarding the nature of the underlying structure. Pertinent considerations of the various profiles selected and appropriate instructions for the application of the method and the elimination of certain effects are given.

It is, of course, impossible to exhaust the infinite number of possibilities occurring in nature, but the author hopes that he has made such a choice as will prove useful in practice. However, it will, at any rate, be possible to deduce any desired profile using the method employed in obtaining the types given in the text.

H. D. HARRADON

SLAUCITĀJS, L.: *Magnetic measurements in the Baltic Sea along the Latvian Coast.* Riga, Latvian Marine Department, Hydrographic Section, 1930 (61 with 3 charts). 25 cm.

Magnetic charts of the Baltic Sea for the epoch 1920 published by various countries differed widely and emphasized both from a scientific and practical point of view the desirability of sea observations. The construction of the Esthonian non-magnetic launch *Cecilie* in 1923 fortunately afforded opportunity for investigations of the magnetic conditions existing in the Baltic. In 1924-26 magnetic surveys were carried out in the waters adjacent to Sweden, Finland, and Esthonia. The paper which is being reviewed discusses the magnetic measurements along the coast and in the waters adjacent to Latvia in 1927-28.

For the efficient control of the constants of the sea-instruments, five base-stations were established, placed equidistantly along the coast. Also the sites chosen were locations where magnetic observations had been taken previously so that a knowledge of secular variation might be obtained. Declination, horizontal intensity, and inclination were determined at the base repeat-stations. In addition thirty stations were established along the coast at which declination-observations were made to supplement the general measurements and make possible the placing of the isogonic lines with greater accuracy.

The *Cecilie* made measurements of declination, horizontal intensity, and vertical intensity at 102 sea-stations spaced at intervals of 8 to 12 nautical miles in the Gulf of Riga and a section of the Baltic Sea, 45 miles wide, lying along the Latvian coast. A liquid compass was employed for declination-observations use being made of a shadow-pin or an azimuth-ring, with the mean error of a determination of $\pm 0^{\circ}.1$. The horizontal intensity was measured with a Bidlingmaier double compass with a probable error of 50 gammas and the vertical intensity with a vertical deflector of the de Cologne type with an accuracy of about 100 gammas.

The ship was swung for the three elements D, H, and Z both in 1927 and in 1928. The deviations on eight equidistant headings were observed and their analysis shows that for all courses they are on the average of the order of 5′ in declination, 40 gammas in horizontal intensity, and 60 gammas in vertical intensity. Thus they are of the order of the accidental observational errors.

All observations have been reduced to the common epoch 1928.5 by means of the data supplied by the magnetic observatory at Rude Skov. Tables are included giving the results on land and sea. Utilizing these, charts of D, H, and Z were prepared and attached to the paper. The lines of equal values are quite complicated with the most conspicuous anomalies in the Gulf of Riga. The extreme element values on the charts are D, $-4^\circ.0$ to $+2^\circ.5$; H, 0.160 to 0.174 c. g. s.; and Z, 0.444 to 0.478 c. g. s.

It is evident that splendid work has been done with the *Cecilie* and the reviewer agrees with the author that her work should be continued in other regions of the Baltic supplemented by land magnetic measurements.

H. F. Johnston

Gutenberg, B.: *Theorie der Erdbebenwellen; Beobachtungen; Bodenunruhe.* (Sections I-III, pp. 1-298, of v. 4, Handbuch der Geophysik herausgegeben von B. Gutenberg, Berlin, Gebrüder Borntraeger, 1929.)

The first part is a mathematical development of the principles of earthquake wave-transmission and application of these to the actual conditions of the Earth. In this way the theoretical paths of waves through the interior of the Earth are deduced. Surfaces of discontinuity and their effects on wave paths and dispersion of energy through reflection and refraction are discussed. The question of depth of focus cannot be separated from that of wave-paths, especially for nearby earthquakes. Theoretical methods of obtaining the depth of focus are developed. The complex surface-waves receive considerable attention.

The second part deals with observations of earthquake-waves and discusses preliminary phases and phases resulting from their reflection, also surface-waves and special attention is given to the phases of nearby earthquakes. Arrival of P- and S-waves over several paths as called for in Jeffreys' theory is fully discussed. Microseismic activity is correlated with a number of natural phenomena, especially meteorological conditions.

N. H. Heck

Berlage, H. P.: *Seismometer, Auswertung der Diagramme.* (Section IV, pp. 299-526, of v. 4, Handbuch der Geophysik herausgegeben von B. Gutenberg, Berlin, Gebrüder Borntraeger, 1930.)

Sieberg, A.: *Geologie der Erdbeben.* (Section V, pp. 627-686, of v. 4, Handbuch der Geophysik herausgegeben von B. Gutenberg, Berlin, Gebrüder Borntraeger, 1930.)

Berlage covers exhaustively the theory and the operation of seismographs and thereby furnishes a useful volume for the working seismologist. Along with an excellent compilation of standard information there is included new material of value. Details of the so-called universal 21-ton seismograph are given. Many types of seismograph and recording apparatus are described. The discussion of the interpretation of the seismogram includes a number of methods for the determination of epicenters. A rather incomplete list of seismological stations of the world is given.

Sieberg discusses earthquake-geology from numerous viewpoints. Starting off with a list of highly destructive earthquakes, he emphasizes especially the relations of different kinds of geological formations to wave-transmission. In advancing theories as to the geological formations related to the origin of earthquakes he gives particular attention to the tectonic type which accounts for about 90 per cent of the total. Intensity-scales and the closely related subject of effect of local geological conditions on

intensity are treated. Earthquakes are discussed from the viewpoint both to the damage to the structures of man and to geological changes of the surface. The theories advanced to explain the origin of earthquakes include volcanic earthquakes. Special means for appraising the intensity of submarine earthquakes are given and great so-called tidal waves are listed and discussed.

N. H. Heck

Williams, Samuel Robinson: *Magnetic Phenomena*. New York, McGraw-Hill Book Company, 1931. (xxii+230). 24 cm.

In the foreword the author sets forth his purpose "to stimulate in upper classmen in college the spirit of research, and possibly enlist the interest of those who have just finished their graduate work and are casting about for a field of investigation which may be inaugurated on their own initiative." In conformity with this purpose, every opportunity is taken to point out new problems for investigation or to show where repetitions of old researches with improved instruments would prove valuable, and the reader becomes more and more impressed with the number and the variety of problems remaining.

The subject matter is divided into eight chapters in an arrangement which presents the various magnetic phenomena in a satisfactory sequence. In the first chapter, "Magneto-magnetics," dealing with the magnetic properties of substances, are discussed the definitions and laws and the mathematical and physical conceptions pertaining to magnetic properties, as well as the instruments and methods by which these properties are determined. The succeeding chapters on magneto-mechanics, magneto-acoustics, magneto-electrics, magneto-thermics, magneto-optics, cosmical magnetism, and magnetic theories and facts discuss the effects of the magnetic properties upon other properties of substances.

The first chapter is an excellently detailed discussion of magnetic properties, occupying about one-half of the book. In it the author consistently points out the need for remodeling old concepts on the basis of the newer knowledge of the structure of matter. He also points out the varying quality of the researches upon which present concepts have been based, a matter not only of interest but also of importance to anyone contemplating or engaged in research.

The remaining chapters are less detailed, but the lack of detail is well compensated for by an extensive bibliography. They present what the author calls "a bird's-eye view of the subject matter of magnetic phenomena." In them is particularly stressed the need for repeating experiments with materials of which the chemical and physical histories are known, since these histories can now be so well obtained by modern methods of pyrometry, microphotography, and chemical and X-ray analysis.

The chapter on cosmical magnetism indicates the need for extending the investigations of the electrical currents in the atmosphere and in the Earth toward furthering the knowledge of magnetism and indicates that years of systematic research lie before those interested in these phases of magnetic phenomena.

In the final chapter are discussed observed magnetic phenomena in their relation to the theories of the structure of the fundamental unit of matter which have been developed chiefly in the last ten or fifteen years. The question is raised as to what the elementary magnet is. Is it the magneton or the electron or, perhaps, the nucleus of the atom? Among the several theories discussed is one suggested by the author, called "The planetesimal hypothesis of magnetism." It appears to fit, better than many others, the observed facts. The author emphasizes the noteworthy fact that all theories, new as well as old, require the rotation of some element within a medium to bring about magnetization. Since the theories do not clearly indicate just what portion of matter turns, if it does turn, the author concludes that "the determination of what the elementary magnet is constitutes the fundamental problem in magnetic research."

The importance of further research in magnetism, the nature of the investigations which should be made, and, to some extent, the methods of investigation, are all presented with a force and in a manner which make the book both stimulating and helpful.

O. W. Torreson

NOTES

1. *Annual Meeting, American Geophysical Union*—The twelfth annual meeting of the American Geophysical Union and of its seven sections will be held in Washington, D. C., April 30 and May 1, 1930.

2. *Award, American Association Prize*—The eighth annual award of the prize of $1,000 of the American Association for the Advancement of Science was made January 3, 1931, to M. A. Tuve, L. R. Hafstad, and O. Dahl, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, for their paper presented at Cleveland on "Experiments with high-voltage tubes." In this paper progress of the Department's program in atomic physics for the study of the fundamental laws of matter and ultimately particularly of magnetism, investigations initiated by Gregory Breit (now of the staff of the New York University and Research Associate of the Carnegie Institution) and continued effectively by the authors, was described. It is to be noted that this prize is awarded each year to the author of a noteworthy contribution to science presented at the Association's annual meeting.

3. *Participation United States, International Polar Year*—Upon the favorable recommendation of the Secretary of State, followed by a special message from President Hoover, February 10, 1931, bills have been introduced in the House and Senate of the Congress of the United States, asking for an appropriation of $30,000 for construction of necessary temporary buildings for housing equipment, purchase of scientific instruments, services of observers, and contingent expenses to permit participation by the United States Government in the International Polar Year program August 1, 1932, to August 1, 1933.

4. *Macquarie Island and King George V. Land*—Wireless dispatches from Sir Douglas Mawson, published in the *Press* of Christchurch, New Zealand, contain information regarding his visits at Macquarie Island and King George V. Land in the course of his present antarctic oceanographical and biological expedition on the *Discovery*. On December 18, 1930, he reported that during a two-day stay at Macquarie Island the weather was stormy and that the wireless-station huts abandoned in 1916 were much weather-worn. The penguin rookeries, which were greatly depleted some years ago, when seals were also decimated, were beginning to recover since the Island has been declared a sanctuary. A number of icebergs were stranded on the shallow bank at the south end of the island. After leaving Macquarie Island the *Discovery* was storm-tossed for several days, rendering the search for the elusive Emerald Island impracticable.

On January 9, 1931, a message was received stating that the party had just embarked, after two days ashore on King George V. Land, where the British flag had been officially hoisted. The hut where the flag was raised twenty years ago was reported still standing, although greatly weather-worn. Magnetic observations, compared with those taken in 1912, seemed to indicate that the magnetic pole is now closer to the station than formerly.

5. *Geophysical News and Review*—So much interest has been shown in articles on geophysical subjects appearing in the Colorado School of Mines Magazine, that it has been decided to publish monthly in that magazine the Geophysical News and Review, which has heretofore been issued as a mimeograph by the Department of Geophysics of the School. The Review will include abstracts of all important geophysical literature appearing in book form or in current magazines.

6. *Earth-Current Observations at Tucson Observatory*—The Mountain States Telephone and Telegraph Company, which serves the area near Tucson, has made available for earth-current work two grounded telegraph-circuits for a period of about one year, subject only to the possibility that these circuits may be required occasionally for commercial use during that time. The circuits extend generally northward from Tucson approximately 35 miles in an air-line to Mammoth and eastward approximately 56 miles in an air-line to Wilcox. The company is already extending the lines to the Tucson Observatory of the United States Coast and Geodetic Survey. *W. J. Rooney*, of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, left from Washington early in March for Tucson to arrange the installation of the electrodes and recording-apparatus as well as to carry out an earth-resistivity survey of the region about the Observatory. The staff of the Observatory will attend to the earth-current work after the installation has been completed.

7. *Personalia*—*J. A. Fleming* has been made Chairman of the reorganized subsidiary Committee of Terrestrial Magnetism and Electricity of the Committee on the Physics of the Earth of the Division of Physical Science of the National Research Council. The scope of the new committee has been augmented by adding to terrestrial magnetism the fields of atmospheric electricity and earth-currents.

Dr. *J. Bartels*, professor at the Forstliche Hochschule, Eberswalde, Germany, and well known for his theoretical researches in terrestrial magnetism, has been appointed as research associate in the Department of Terrestrial Magnetism of the Carnegie Institution of Washington for one year, beginning April 1, 1931.

Prof. *G. Melander* retired from the directorship of the Central Meteorological Institute of Finland on January 9, 1931. He has been succeeded provisionally by Dr. *J. Keränen*.

Prof. Dr. *Wilhelm Schmidt*, on November 25, 1930, succeeded the late Prof. *F. M. Exner* as director of the Zentralanstalt für Meteorologie und Geodynamik and as professor of Geophysics in the University of Vienna. His address in the future will be: Wien XXX/1, Hohe Warte 28.

Dr. *Stefan Hlasek* retired, on February 1, 1931, from the directorship of the Central Meteorological Institute of Poland. He is succeeded in this capacity by Dr. *Jean Lugeon*.

8. *Errata*—The following corrections should be made in the December 1930 number of the Journal: p. 253, for Katherine B. Clark read Katharine B. Clarke; p. 254, the minus signs under column "*Y*" in "Marche séculaire" should be positive signs.

NOTICE

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

ANDRESEN, P. Ueber eine Aenderung der Deviationsformel. Berlin, Ann. Hydrogr., Jahrg. 58, Heft 11, 1930 (390-393).

BATAVIA. Observations made at the Royal Magnetical and Meteorological Observatory at Batavia, v. 49, 1926. Published by order of the government of Netherlands Indies, by Dr. S. W. Visser, Acting Director. Batavia, 1930 (xix+116 with 3 plates of curves). 36 cm. [Contains magnetical records Batavia-Buitenzorg for 1926.]

BOSLER, J. Sur les relations des orages magnétiques avec les courants telluriques. Paris, C.-R. Acad. sci., T. 191, No. 20, 1930 (961-963).

BRÜCKMANN, W. Le levé magnétique de la Suisse. Arch. Sci. Phys., Genève, v. 12, 1930 (237-243). [Has map showing lines of equal magnetic declination.]

CHAPMAN, S. AND V. C. A. FERRARO. A new theory of magnetic storms. Nature, London, v. 126, No. 3169, 1930 (129-130).

COLDEWEY, H. New precise liquid compass card. Hydrogr. Rev., Monaco, v. 8, No. 2, 1930 (188-190). [English abstract of an article published in Ann. Hydrogr., Berlin, Heft 6, 1929 (196-199).]

LAJOLET, P. Les perturbations de la déclinaison magnétique à Lyon pendant le mois de septembre 1930. Saint-Genis-Laval, Bul. Obs. Lyon, T. 12, No. 12, 1930 (362).

MMLER, W. Die magnetische Azimutgleiche. Berlin, Ann. Hydrogr., Jahrg. 58, Heft 11, 1930 (397-399).

ACKSON, W. E. W. Magnetic values for Agincourt and Meanook. (A summary of the results obtained during the years 1927-1928.) Toronto, J. R. Astr. Soc. Can., v. 24, No. 10, 1930 (457-465).

KALINOWSKI, ST. Wyniki spostrzezeń magnetycznych w Swidrze. (Résultats des observations magnétiques à Swider, Pologne) 1921-1929. A. Zboczenie (déclinaison). Warszawa, Trav. Obs. Mag. à Swider, No. 4, 1930 (x+117). 28 cm. [Texte français.]

KUBO, T. The result of the magnetic survey on some of the islands in the southern part of the Japan Sea. J. Oceanography, Kobe, v. 2, No. 2, 1930 (265). [Text in Japanese. Table of results of observations in English.]

LA COUR, D., ET V. LAURSEN. Le variomètre de Copenhague. Variomètre magnétique pour la force horizontale. Copenhague, Inst. Mét., Comm. Mag., No. 11, 1930 (11). 25 cm.

LEE A. W. A new relation between atmospheric electricity and terrestrial magnetism. London, Met. Office, Prof. Notes No. 58, 1930, 8 pp. 24 cm.

MAURER, H. Regions of magnetic perturbation. Hydrogr. Rev., Monaco, v. 8, No. 2, 1930 (194). [Reproduced from "Nachrichten für Seefahrer" Dec. 14, 1929 (1640).]

NIPPOLDT, A. Secular variations of terrestrial magnetism. Hydrogr. Rev., Monaco, v. 8, No. 2, 1930 (98-104). [Reproduced from the "Topo-Hüdrograafia Aastara-amat," Tailinnas No. 9, 1930 (65-71).]

Verwertung magnetischer Messungen zur Mutung für Geologen und Bergingenieure. Berlin, Verlag von Julius Springer, 1930 (iv+74 mit 36 Taf.). 24 cm.

ONO, S. A note on the magnetic characterization of days. Ann. Rep. Kakioka Mag. Obs. 1926, Tokyo, 1927 (5-12).

PETERS, W. J. Tilting deviations in magnetic declinations. Hydrogr. Rev., Monaco, v. 8, No. 2, 1930 (191-193). [Abstract of a article having same title appearing in Terr. Mag., v. 34, 1929 (93-115).]

RUSSELTVEDT, N., AND A. GRAARUD. The scientific results of the Norwegian Arctic Expedition in the Gjöa 1903-1906 under the conduct of Roald Amundsen. Part III. Terrestrial magnetism photograms. Geofys. Pub., Oslo, v. 8, 1930 (17 with 191 pls.). [The present Part III contains the reproduction of the magnetograms obtained at Gjöahavn from October 31, 1903 to June 1, 1905, together with the

accompanying explanatory text. Parts I and II, the former of which will be devoted to astronomy and meteorology, and the latter to terrestrial magnetism, will be published later.]

Ryd, V. H. On the scale value and the base value of the H-variometer. Copenhague, Inst. Mét., Comm. Mag., No. 12, 1930 (11). 25 cm.

Slaucitajs, L. Magnetic measurements in the Baltic Sea along the Latvian Coast. Riga, Hydrogr. Sec., Latvian Marine Dept., 1930 (61 pp. with 3 maps). 26 cm. [Gives results of magnetic measurements made during the cruises of the "Cecilie" in the Baltic Sea and at various Latvian coastal stations with maps giving isogonic lines, lines of equal horizontal intensity, and lines of equal vertical intensity for the epoch 1928.5.]

Somers, G. B. Anomalies of vertical intensity. Correlation of the anomalies of vertical intensity of the Earth's magnetic field with the regional geology of North America. Repr. Colo. School Min. Mag., v. 20, Aug.-Dec., 1930; v. 21, Jan.-Feb.. 1931 (64).

Southampton, Ordnance Survey. Description of the portable magnetometer of the Ordnance Survey built by the Cambridge Instrument Co. Ltd. Hydrogr. Rev., Monaco, v. 8, No. 2, 1930 (185-187). [Abstract of descriptive pamphlet issued by the Ordnance Survey, Southampton, 1930.]

Tashkent, Geophysical Observatory. Bulletin of the Geophysical Observatory of Tashkent. No. 1, January-June 1928. Tashkent, Met. Inst. Middle Asia, 1929 (40). 25 cm. [Contains values of the atmospheric potential-grandient and conductivity and of the elements of terrestrial magnetism for the period covered by the Bulletin.]

Tokyo, Central Meteorological Observatory. The annual report of the Kakioka Magnetic Observatory, Japan, for the year 1924. Tokyo, 1926 (39 with 10 pls.). 30 cm. [Contains results of magnetic observations February to December 1924. This is the first report of the new series of publications giving results obtained since the disastrous earthquake of September 1, 1923.]

The annual report of the Kakioka Magnetic Observatory, Japan, for the year 1925. Tokyo, 1926 (39 with illus. and 10 pls.). 30 cm. [Contains besides the results of magnetic observations, brief description of observatory with illustrations of instruments and buildings.]

The annual report of the Kakioka Magnetic Observatory, Japan, for the year 1926. Tokyo, 1927 (39+15 with 20 pls.). 30 cm. [Contains besides the results of magnetic observations for 1926, three appendices: Observations of sudden commencements of magnetic storms at Kakioka in 1926; A note on the magnetic characterization of days, by S. Ono; The magnetic variability observed at Kakioka Magnetic Observatory, Japan, for 1926.]

Observations of sudden commencements of magnetic storms at Kakioka in 1926. Ann. Rep. Kakioka Mag. Obs. 1926, Tokyo, 1927 (1-4).

The magnetic variability observed at Kakioka Magnetic Observatory, Japan, for 1926. Ann. Rep. Kakioka Mag. Obs. 1926, Tokyo, 1927 (13-15).

The annual report of the Kakioka Magnetic Observatory, Japan, for the year 1927. Tokyo, 1930 (39 with 19 pls.). 30 cm. [Contains results of magnetic observations at Kakioka for the year 1927.]

The magnetic variability observed at Kakioka Magnetic Observatory, Japan, for 1927. Ann. Rep. Kakioka Mag. Obs. 1927, Tokyo, 1930 (41-43).

United States Coast and Geodetic Survey. Magnetic declination in the Philippine Islands in 1925. Manila, Bureau of Printing, 1930 (33 with map). 23 cm.

Annual report of the Director, United States Coast and Geodetic Survey to the Secretary of Commerce for the fiscal year ended June 30, 1930. Washington, D. C., Dept. Comm., U. S. Coast and Geod. Surv., 1930 (47 with 10 maps.). 23 cm. [Contains general account of the magnetic and seismological work for the period in question.]

United States Naval Observatory. Annual report of the Naval Observatory for the fiscal year 1930. Washington, D. C., Govt. Print. Off., 1930 (22). 23 cm. (Report of Compass Division, pp. 4-6.]

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B—Terrestrial and Cosmical Electricity

LIVERTI, G. Misure di radioattività atmosferica. Torino, Atti Acc. sc., v. 64, 1929 (97-103).

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RÜCHE, E. Experimente zu Störmers Polarlichttheorie. Physik. Zs., Leipzig, Jahrg. 31, Nr. 22, 1930 (1011-1015).

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Wo erreichen kosmische Eletronenstrahlen die Erdkugel? Leipzig, Physik. Zs., Jahrg. 32, Nr. 1, 1931 (31-33).

RÜCHE, E., UND W. ENDE. Demonstrationsversuche zu Störmers Polarlichttheorie. Physik. Zs., Leipzig, Jahrg. 31, Nr. 22, 1930 (1015-1016).

ORLIN, A. Die Sternzeitschwankungen der Höhenstrahlung. Naturw., Berlin, Jahrg. 19, Heft 2, 1931 (37-39).

JCHS, J., UND J. SCHOLZ. Untersuchungen über luftelektrische Phänomene und die atmosphärischen Störgeräusche der Radiotelegraphie. Beitr. Geophysik, Leipzig, Bd. 27, Heft 2, 1930 (176-216).

ISH, O. H. The natural electric currents in the Earth's crust. Sci. Mon., New York, N. Y., v. 32, Jan., 1931 (5-21 with illus.).

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Ein experimentelles Argument für den stellaren Ursprung der Ultrastrahlung. Berlin, Naturw., Jahrg. 18, Heft 50, 1930 (1094-1096.)

JLBURT, E. O. Ultraviolet light theory of aurorae and magnetic storms. (Continued) Phys. Rev., Menasha, Wis., v. 36, No. 10, 1930 (1560-1569).

Atmospheric ionization by cosmic radiation. Phys. Rev., Menasha, Wis., v. 37, No. 1, 1931 (1-8).

ÄHLER, K. Messungen der Anzahl der atmosphärischen Elektrizitätsträger bei Niederschlägen. Beitr. Geophysik, Leipzig, Bd. 27, Heft 2, 1930 (226-240).

DWIGER, H. VON. Das elektrische und magnetische Feld um einen "Erdstrahler." Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 1, Heft 2, 1930 (189-226).

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WESTPHAL, W. Beobachtung eines Kugelblitzes. Naturw., Berlin, Jahrg. 19, Heft 1, 1931 (19-20). [Brief description of a case of ball lightning observed at Berlin during electrical storm on November 23, 1930.]

WIGAND, A., J. SCHUBERT UND E. FRANKENBERGER. Ein neues Verfahren der luftelektrischen Raumladungsmessung. Zs. Geophysik, Braunschweig, Jahrg. 6, Heft 8, 1930 (458-463).

C—Miscellaneous

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The Askania aircraft compasses. Hydrogr. Rev., Monaco, v. 8, No. 2, 1930 (127-131).

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INTERNATIONAL METEOROLOGICAL ORGANIZATION. Premier rapport de la Commission Internationale de l'Année Polaire 1932-1933. (Compte-rendu des travaux de la Commission pendant sa première année de travail. Procès-verbaux des séances de la réunion à Leningrad, août 1930.) Leyde, Imprimerie Ed. Ijdo, S. A., 1930 (iv+152). 24 cm.

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Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 36 JUNE, 1931 No. 2

A NEW THEORY OF MAGNETIC STORMS

BY S. CHAPMAN AND V. C. A. FERRARO

PART I—THE INITIAL PHASE

1—Introduction and summary
2—The motion of an infinite plane-slab stream in a uniform magnetic field
3—The motion of a cylindrical stream in a uniform magnetic field
4—The motion of a neutral ionized system of any form in a uniform magnetic field
5—The internal steady motion of a neutral ionized stream in a non-uniform magnetic field
6—The phenomena accompanying the advance of a solar ionized stream into the Earth's field

1—*Introduction and summary*

1.1—Many attempts have been made, but hitherto without success, to explain how magnetic storms are produced. The present further attempt is described with a due sense of the pitfalls that abound in this difficult field of speculation. Possibly the fate in store for our theory is only to warn future theorists against some fallacy into which we have unwittingly fallen; yet if so, our work, and that of our critics, may be of value to later writers, just as we have benefited by the labours of past speculators and their critics. But our theory would of course not have been put forward without some confidence on our part in its substantial truth.

1.2—On good grounds, almost every theory of storms* has ascribed them to the action of something propagated to the Earth from the Sun. Lord Kelvin[1] in 1892 showed that the storms could not be directly due to variations in the Sun's magnetic field, and Hale's[2] subsequent measurements of the Sun's field confirm this. The postulated solar agent has therefore been either some corpuscular emission, or ultraviolet radiation.

1.3—"Corpuscular" theories differ as regards the nature and speed of the solar particles, and as to their mode of action when they approach the Earth. The particles are supposed to be electrical, and in the earlier theories, wholly or mainly of one sign; more recently the streams have been thought of as containing charges of both signs, and nearly neutral.

At first storms were regarded as the direct manifestation of the magnetic field of an electric current consisting of a stream of moving

*"Storm" or "field" will throughout this paper mean magnetic storm and magnetic field, unless otherwise indicated.

[1]Proc. R. Soc., 52, 307-308 (1892).

[2]Astroph. J., 38, 27-98, 99-125 (1913); 47, 206-254 (1918). [Contrib. Mt. Wilson Obs., Nos. 71, 72, and 148.]

electric charges of like sign. Lodge,[3] in 1909, proposed this view, suggesting that the particles were electrons; he supposed them to travel past the Earth in a straight stream (though such a stream could not really explain the known characteristics of a storm).

Birkeland[4] in 1896 pointed out that electrons traveling toward the Earth would be deflected by the Earth's field. He made experiments in which cathode-rays were projected towards a small magnetized sphere, and showed that their distribution near the sphere was largely governed by the field, which, in particular, guided many of the electrons towards the polar regions. This gave the first insight into the physical cause both of the special intensity of magnetic disturbance in high latitudes, and of the polar incidence of aurorae. Since then the theories of the two phenomena have been linked together. Birkeland[5] developed his ideas in three extensive and important memoirs, of 1901, 1908 and 1913; these form the most detailed and comprehensive theoretical discussion of magnetic storms hitherto published. His work has been continued and developed in Norway by Störmer[6] and Vegard,[7] but with particular reference to aurorae rather than to magnetic storms. Birkeland supposed the corpuscles that are responsible for aurorae and magnetic storms to be electrons of very high velocity, nearly equal to that of light. Störmer and Vegard have considered also the possibility that they may be slower electrons or (positive) α-particles.

Schuster[8] criticized storm-theories of the type proposed by Lodge and Birkeland, on the ground (among others) that, without unreasonably high velocity and energy, the stream would not hold together against the mutual repulsion of its parts during the passage from the Sun to the Earth. He regarded Birkeland's *auroral* theory, however, as still tenable (§ 1.31), if the electron-stream was suitably rare (too rare to produce an appreciable direct magnetic field).

1.31—Theories of the type considered in § 1.3 attribute the storm to electric currents flowing mainly in the space outside the Earth's atmosphere—the region being, indeed, many times larger than the Earth in linear extent. An alternative totally different view is that the currents which produce the storm flow wholly in the Earth's atmosphere. This view was suggested by the dynamo-theory of the daily magnetic variations, originated by Balfour Stewart[9] and developed quantitatively by Schuster in 1889[10] and 1905.[11] In reference to magnetic disturbance this view seems to have been first proposed by Ad. Schmidt[12] (1899), who regarded the typical "element" of magnetic disturbance as being due to a moving current vortex in the upper atmosphere. The same idea seems to have been favored, though not definitively, by van Bemmelen[13] (1900), relative to the simple world-wide component of the

[3] Nature, **81**, 425-426 (1909).

[4] Arch. Sci. Phys., Genève, **4**, 497 (1896).

[5] Skr. Vid. selsk., No. 1 (1901); Norwegian Aurora Polaris Expedition, **1**, Sect. 1 (1908), Sect. 2 (1913).

[6] Terr. Mag., **35**, 193-208 (1930) and references there given.

[7] Wien-Harms, Handbuch der Experimentalphysik, **25**, 385-476 (1928) and earlier references there given.

[8] Proc. R. Soc., A, **85**, 45-50 (1911).

[9] Encyclopaedia Britannica, 9th ed., **16**, 181-184 (1878).

[10] Phil. Trans. R. Soc., A, **180**, 467-518 (1889).

[11] Phil. Trans. R. Soc., A, **208**, 163-204 (1898). See also S. Chapman, ibidem. **213**, 279-321 (1913); **218**, 1-118 (1919).

[12] Met. Zs., **16**, 385-397 (1899).

[13] Terr. Mag., **5**, 123-126 (1900).

storm-field corresponding to the diminution of horizontal force during the main phase of the storm. These writers expressed no views as to how the currents were set up. In 1905, and again in 1911, Schuster advocated the same "atmospheric-current" hypothesis; he amplified it by proposing that the currents are impelled by electromotive forces which are always present in the upper atmosphere, their effect, however, being magnified from time to time by increased ionization and conductivity of the air, due to the entry and impact of solar corpuscles. He considered that the energy of the storm is drawn from the kinetic energy of the Earth's rotation; he did not explain or discuss the detailed characteristics of the storm-field.

In the concluding part of a paper[14] devoted mainly to an observational analysis of storms, Chapman made the first detailed attempt to develop a storm-theory of the atmospheric-current type. His aim was to explain the very definite characteristics of storms brought out by his analysis of them, following that of Moos.[15] He ascribed the currents to the action of a stream of corpuscles mainly of one sign of charge. While qualitatively successful within certain limits, the theory, on further examination, proved to have many defects, and it was afterwards given up by its author; for a time it was still upheld by Angenheister,[16] with the modification that horizontal motion was supposed to accompany the main, vertical, air-motion considered in the theory.

Lindemann[17] in 1919 criticized Chapman's numerical development of his theory, chiefly on the ground that it involved an accumulation of charge in the Earth's atmosphere which would, by electrostatic repulsion, prevent the supposed continuous entry of further charges.

In his first paper Chapman did not consider the storm-data derived from polar stations, though proposing to do so in a later paper[18]—an intention fulfilled in 1927. The new features then brought out were inconsistent with his dynamo-theory of storms. While abandoning this particular theory, he still favored the atmospheric-current hypothesis, though unable to construct a theory of this type which would fit the observed facts.

1.32—Lindemann added to his criticism of Chapman's theory a suggestion that the latter might be preserved in substance, if the supposed stream of charged particles, mainly of one sign, were replaced by a neutral but ionized stream or cloud. On entry into the Earth's atmosphere the electrons would be stopped at a higher level than the more massive positive ions, and a vertical separation of charge would result, which he took to be the essential requirement in Chapman's theory.

He showed how a neutral ionized stream might originate at the Sun and travel to the Earth, without appreciable recombination, and with a velocity of about 8×10^7 cm/sec (or 800 km/sec). He did not consider its terrestrial effects, though he suggested that it might produce aurorae as well as storms.

In 1923 Chapman[19] examined whether such an ionized stream, strictly neutral electrostatically, would be deflected in the Earth's magnetic field so as to impinge upon the atmosphere mainly in the polar regions.

[14]Proc. R. Soc., A, **95**, 61-83 (1918).
[15]Colaba Magnetic Data, **2**, Chap. 10 (1910).
[16]Göttingen, Nachr. Ges. Wiss., 1-42 (1924).
[17]Phil. Mag., **38**, 669-684 (1919).
[18]Proc. R. Soc., A, **115**, 242-267 (1927).
[19]Cambridge, Proc. Phil. Soc., **21**, 577-594 (1923).

He concluded that it would be deflected only very slightly, and not in such a way as to produce the aurora polaris. It may also be noted (though this was not stated in Chapman's paper) that, contrary to Lindemann's supposition, the entry of the particles into the atmosphere would not produce the effects ascribed in Chapman's theory to a set of charges mainly of like sign. No alternative explanation of storms appeared to result from the motion of the neutral ionized stream near the Earth.

1.4—Recently (1929) Hulburt and Maris[20] have endeavoured to explain the main facts[14, 18] about storms, and also about aurorae, by the hypothesis that these phenomena are produced by *terrestrial* corpuscles, temporarily separated from the Earth's atmosphere, to a distance of about five earth-radii, by the action of solar ultraviolet light. While their theory is ingenious and interesting, according to Chapman[21] it does not in reality succeed in explaining magnetic storms.

1.5—During the past three years we have made repeated attempts to construct a satisfactory corpuscular theory of storms. The tendency for magnetic disturbance to recur at intervals of a solar rotation, discussed and interpreted by Maunder,[22] and further confirmed by Chree,[23] seemed to us to afford a strong presumption that, in some way, streams of solar corpuscles were the cause of storms. The interesting work of Milne[24] on the emission of high-speed corpuscles from the Sun further encouraged this view. A re-examination[25] of the conditions of passage of the stream from the Sun to the Earth disposed of our lingering hope that the stream might carry some small residue of charge which would at least suffice[26] to explain the production of aurorae, by permitting the stream to be deflected in the same way as separate corpuscles are in Störmer's theory (though to a smaller extent); our work confirmed Lindemann's conclusion that the only admissible kind of stream is one that is electro-statically neutral to a very high degree of approximation.

After many unsuccessful endeavours to find how such a stream could produce a storm when near the Earth, we returned to consider whether, as Chapman[27] suggested in 1920, the Sun could emit streams which, though having no space-charge, carry an electric current by reason of a difference between the streaming velocities of the positive ions and the electrons. According to Milne's emission-theory, the positive ions are projected outwards by selective radiation-pressure, while the radiative acceleration of the electrons is much smaller. The electrons must be drawn after the ions by electrostatic forces, but it seemed possible that they might follow the ions at a somewhat slower rate, so that, while the number of each per unit volume was the same, and the space-charge consequently zero, the stream would convey a positive current. An ideal problem bearing on this question was devised by us, and solved by Ferraro;[28] the result convinced us that the stream could not carry any appreciable current, or possess an appreciable magnetic field. Thus

[20] Phys. Rev. **33**, 412-431 (1929); **34**, 344-351 (1929); **36**, 1560-1569 (1930).
[21] Mon. Not. R. Astr. Soc., Geophys. Sup., **2**, 296-300 (1930).
[22] Mon. Not. R. Astr. Soc., **65**, 2-35, 538-559, 666-681 (1904).
[23] Phil. Trans. R. Soc., A, **212**, 75-116 (1912); **213**, 245-277 (1913).
[24] Mon. Not. R. Astr. Soc., **86**, 459-473 (1926).
[25] Chapman and Ferraro, Mon. Not. R. Astr. Soc., **89**, 470-479 (1929).
[26] Q. J. R. Met. Soc., **52**, 225-236 (1926).
[27] Phil. Mag., **40**, 665-669 (1920).
[28] Mon. Not. R. Astr. Soc., **91**, 174 (1930).

the only kind of stream available for a corpuscular theory of storms was one of the kind proposed by Lindemann, neutral, ionized, and with the same streaming velocity for both the ions and electrons.

1.6—If magnetic storms are due to solar corpuscles, as still seemed to us likely, it was therefore necessary to return once more to the problem of the motion of such a stream near the Earth, despite the earlier failure to find how the motion could explain a storm.

The properties to be assigned to the streams were necessarily largely hypothetical, since as yet we have no direct evidence even as to their existence. A possible method of testing the latter, and, if successful, of determining the density of the stream, has been suggested by Chapman,[29] but not yet tried; considerations relating to the solar atmosphere, however, render it likely that at a distance from the Sun equal to the radius of the orbit of the Earth, the density (apart from any change brought about by a deflecting influence of the Earth's magnetic field) will lie between 2×10^9 and 20 ions/cc.

The work of Lindemann[17] and Milne[24] suggests that the streaming velocity will be at least of the order 10^8 cm/sec (1,000 km/sec); distinctly higher velocities seem possible, indeed, since storms appear to be associated with disturbed areas on the Sun, where higher temperatures and greater radiation-pressure may operate. The geometry of the streams, for any given velocity, taking account of the solar rotation, has been worked out;[29] though the individual particles travel almost radially outwards from the Sun, the outline of the stream rotates with the Sun; a continuous stream will overtake the Earth in its orbital motion, approaching on the *post meridiem* (P. M.) side; the surface of the stream, if undisturbed by the Earth's magnetic field, would cross the Earth in about 35 seconds.

The radius of cross section of the stream at the distance of the Earth will depend on the area of the emitting region on the Sun, but if it is assumed (with some plausibility) that the duration of a storm is approximately the same as the period during which the Earth is enveloped in the stream, the radius may be estimated as about 10^{12} to 10^{13} cm, or 2×10^3 to 2×10^4 Earth-radii.

According to Milne's emission-theory, the stream may include *neutral* atoms as well as ions and electrons; the atoms and ions would be emitted by the same process, and their numbers may be expected to bear some roughly constant ratio to each other. The neutral particles will of course travel through the Earth's magnetic field without deflection, and impinge on the sunlit hemisphere, there increasing the ionization of the atmosphere by impact with the air-molecules. This excess ionization may indirectly affect the development of the magnetic storm, but the neutral atoms are unlikely to play any direct or essential part in producing the storm.

1.61—If the stream is composed of N positive ions and N electrons per cc (N varying from point to point), which have random motions corresponding to a temperature T, taken to be 6,000°, then the mean free-path l of the electrons is about $2 \times 10^{11}/N$ cm, according to one mode of estimation.[30] Another method is to suppose that a collision (terminating a free-path) occurs if a particle suffers a deflection of 90° or more: in a rare stream—such as will be considered here—this deflection will be produced mainly by the cumulative effect of a series of feeble

[29] Mon. Not. R. Astr. Soc., **89**, 456, 466 (1929).

encounters (rather than by a single encounter).* On calculation, we find very nearly the same value for the mean free-path as that given above by the first method.

The coefficient of diffusion D of the ions and electrons relative to one another is very high.[31] For singly charged ions (of any kind) at 6000°, it is approximately $1.8 \times 10^{18}/N$ $(1 - 0.048 \log N)$. Thus ND is nearly constant over a wide range of values of N; for example, 10^{-18} ND is 3.5, 4.6, and 6.5 for $N = 0.1$, 10^4, and 10^9.

The electric conductivity σ of the gas is proportional to ND, and therefore is nearly the same over a wide range of N. For $ND = 5 \times 10^{18}$, $\sigma = 1.6 \times 10^{-9}$ e.m.u.; this conductivity is considerable, though much less than that of copper (6×10^{-4}) at ordinary temperatures.

If there are neutral atoms in the stream, as well as ions and electrons, the estimates of l, D, and σ must be somewhat reduced, but probably only by a factor of order one-half or one-third.

In the presence of a magnetic field of intensity H, the ions and electrons may be in certain cases spiral in paths of radius R, where $R = m\,v/e\,H$, m and v being the mass and velocity of a particle, and e its charge in e.m.u. For an electron $m\,v/e = 2.83$, and for hydrogen (H^+) and calcium (Ca^+) ions respectively it is 1.26×10^2, 8.06×10^2. When this spiralling occurs the contributions of the electrons and ions to σ are reduced. In a rare stream, in which the *ions* contribute practically the whole of the current, σ is approximately reduced in the ratio of $(m_i/m_e)\ [R^2/(R^2 + l^2)]$, m_i and m_e denoting respectively the masses of an ion and an electron.

1.7—Our re-examination of the motion of a neutral ionized stream in a magnetic field indicates that Chapman's investigation[19], though defective in some points, is correct as regards one of its main conclusions, namely, that within the stream the ions and electrons can move together nearly rectilinearly, without spiralling,† and with only a slight deflection by the field. The field tends to deflect the ions and electrons differently, and so to separate them; but this tendency is resisted by the electrostatic field thereby set up, and all that results is a slight "polarization" of the stream, involving a surface charge-distribution, and also in general, if the polarization is not uniform, a volume charge-distribution. The electrostatic energy of the polarization is drawn from the kinetic energy of the stream, which is slightly slowed down.

In Chapman's investigation the stream was supposed to envelop the Earth completely, its lateral surface being so far from the Earth that the surface-charge there was negligible. In our work we have carefully examined this and other surface-effects, which were either neglected by him, or did not enter into the problem that he considered, namely, that of a stream in the *steady state*. We find them to be of primary importance, however, in the production of a magnetic storm, which depends essentially on surface-phenomena associated with the approach of the stream towards the Earth. Chapman's failure to recognize the mode of production of the storm is explained by the limitation which he placed on his problem at the outset.

1.8—The surface-effects that we have investigated are of three

*Cf. J. Jeans, Astronomy and Cosmogony, p. 311 (1928).

[30] Mon. Not. R. Astr. Soc., **89**, 79 (1928).

[31] Mon. Not. R. Astr. Soc., **82**, 292-297 (1922); Persico, Mon. Not. R. Astr. Soc., **86**, 93 (1926).

†It is assumed that the streaming velocity is many times larger than the thermal velocities of the ions and electrons.

kinds. The mere presence of the surface-charge, uncomplicated by other effects that occur in general, is exemplified in the case of an infinite-plane-slab stream moving through a uniform magnetic field (§ 2); here the surface-charge is stable, and its sole function is to neutralize the deflecting tendency of the magnetic field on the particles inside the stream.

The second effect occurs in the next simplest case, that of a cylindrical stream of any cross-section moving through a uniform field. Here the surface-charge density is non-uniform, and there is an electric field *outside* the stream as well as within it: the surface-charge is repelled from the surface and tends to escape.

The third effect appears (together with the other two) in the case of a stream moving in a non-uniform field; for definiteness, suppose the stream is advancing into a region of increasing intensity. The polarization and the surface-charge on a particular section of the stream increase as it moves along; the deflecting tendency of the field inside the stream is nearly neutralized, as before, and the surface-charge continuously escapes; but now, in addition, electric currents are induced, in and near the surface of the stream, which tend to maintain the magnetic field uniform inside the stream—that is, to reduce its intensity as the stream advances into the stronger field; conversely the currents increase the field outside the stream. The stream may be thought of as offering resistance to its interpenetration by the tubes of magnetic force, so that it pushes them before it in its motion, increasing the magnetic intensity in front of it, and reducing it within its surface. This third effect is, we think, the cause of the initial phase of a storm, while the second (the escape of surface-charge) is important in producing the main phase.

The magnetic field exerts a mechanical force on the surface-currents, and tends to oppose the advance of the stream into the more intense field. In the case of a stream from the Sun advancing towards the Earth, a hollow space round the Earth is formed in the stream; the hollow is open at the back of the Earth (as viewed from the Sun); this is illustrated in Figure 1. The hollow gradually shrinks, at a diminishing rate as the surface advances; meanwhile the surface-layer is increased in density by the inpouring of the particles coming on from behind, which are not retarded till they enter the current-carrying layer. If the stream were directed towards the Earth for an indefinite period, the hollow would eventually close up on to the Earth, and the conditions would become in some ways similar to those of the problem discussed by Chapman;[19] but by that time the storm (or at least some of its most important phases) would be over. However, owing to the rotation of the Sun the stream may pass on before this occurs; part of the stream which has collected near the Earth remains for a time, probably in the form of a ring round the equator; this gradually disappears by the passage of the ions and electrons, along the Earth's lines of force, into the atmosphere in high latitudes.

2—*The motion of an infinite plane-slab stream in a uniform magnetic field*

2.1—The velocity u of the stream to be considered will be of the order of 10^8 to 10^9 cm/sec, so that $(u/c)^2$, where c denotes the velocity

of light, is of the order 10^{-3} to 10^{-5}; in general we shall neglect terms of the second degree in u/c, as compared with unity.

The magnetic field of the Earth has its maximum intensity at the poles (except for a few limited disturbed localities), where the intensity

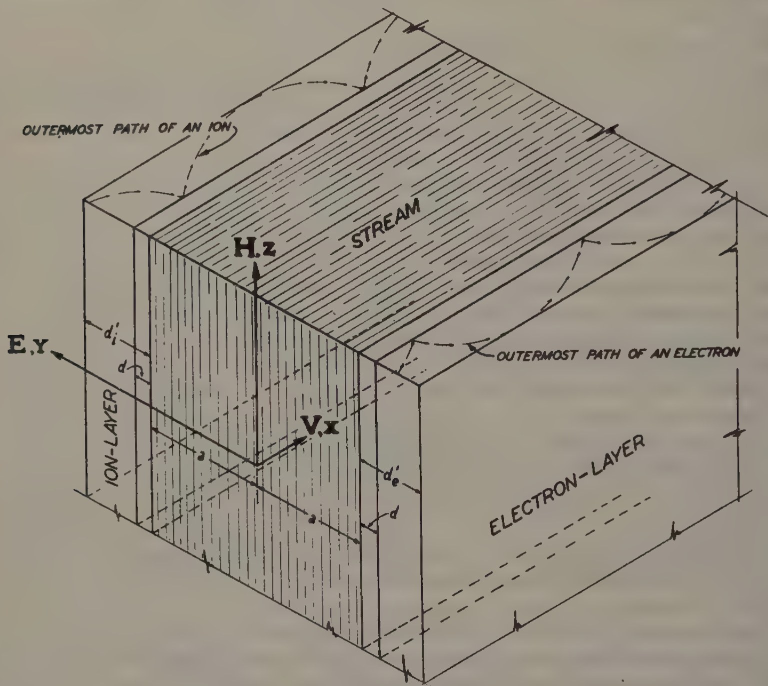

FIG. 1

H is less than one gauss. The fields to be considered will therefore be of this or smaller intensity.

The motion of a single particle of mass me, velocity $\mathbf{v}$ and charge e (e.s.u.) in a uniform electric and magnetic field E, H, is given by the equation*

$$m\dot{\mathbf{v}} = e\mathbf{E} + (e/c)\,\mathbf{v}_\wedge\mathbf{H}, \tag{1}$$

the solution of which is, if the direction of $\mathbf{E}$ and $\mathbf{H}$ form a right-angle

$$v = c(\mathbf{E}_\wedge\mathbf{H})/H^2 + \mathbf{v}_0; \tag{2}$$

$\mathbf{v}_0$ is a vector, the value of which can be chosen arbitrarily at a particular instant, and which thereafter satisfies the equation

$$\dot{\mathbf{v}}_0 = (e/mc)\,\mathbf{v}_{0\wedge}\mathbf{H}; \tag{3}$$

thus the component of $\mathbf{v}_0$ parallel to $\mathbf{H}$ is constant, while the normal component rotates about the direction of $\mathbf{H}$ with the angular velocity $\omega = eH/mc$. The motion is therefore trochoidal, and the radius R of the circular component of the motion is v_0/ω or mcv_0/eH (taken positive whatever the sign of e).

*The notation $\mathbf{a}_\wedge\mathbf{b}$ is used for the vector-products of two vectors, $\mathbf{a}$, $\mathbf{b}$.

If $\mathbf{E} = E\mathbf{y}$, $\mathbf{H} = H\mathbf{z}$, (2) becomes

(4) $$\mathbf{v} = (cE/H)\,\mathbf{x} + \mathbf{v}_o,$$

where $\mathbf{x}$ is the unit vector $\mathbf{y}_\wedge\mathbf{z}$; if $\mathbf{v}_o$ has no $\mathbf{z}$ component, the motion is purely in the $\mathbf{x}$, $\mathbf{y}$ plane.

2.2—Consider a uniform "slab" of neutral ionized gas, *at rest*, between two infinite parallel planes $y = \pm a$, in the presence of uniform applied electric and magnetic fields $E\mathbf{y}$, $H\mathbf{z}$ throughout space. The gas can be maintained in equilibrium by electrically charged surface-layers, containing either ions only (at $y > a$) or electrons only ($y < -a$), the charge per unit surface-area being $\sigma = E/4\pi$; between the planes $y = -a$ and $y = a$ the electric field due to these layers neutralizes the applied electric field $E\,\mathbf{y}$.

Let the density of the singly charged positive ions be N per cc, and likewise that of the electrons, not only in the neutral gas between $y = \pm a$, but also initially in the surface-layers; the thickness d of these layers is therefore given by $\sigma = Nde$, where e is the electronic charge (in e.s.u.). Alternatively the density (N_i) of the ions in the positively charged layer, and that (N_e) of the electrons in the negative layer may be different from N and from each other, in which case the thickness of the layers (d_i and d_e, say) will be related by the equations

$$N_i d_i e = N_e d_e e = \sigma$$

The whole set of charges being initially at rest, those in the interior neutral region will remain so, but not those in the surface-layers. In the stratum at the distance θd from the inner surface of either layer the charges will describe cycloidal paths; for initially and (as will appear) always, the electric force on this stratum is $\theta\mathbf{E}$; under the influence of this and the magnetic field H, and subject to the initial conditions $y = \pm(a + \theta d)$, $\mathbf{v} = 0$, the subsequent motion is given by

(5) $$\mathbf{v} = (\theta cE/H)\,\mathbf{x} + \mathbf{v}_o,$$

where initially $\mathbf{v}_o = -(\theta cE/H)\,\mathbf{x}$; thus the mean velocity and the "circular" velocity are equal, so that the path is a cycloid; the radius R of the circular motion is $\theta mc^2E/eH^2$, and the y-coordinate at any time t is given by

(6) $$y = \pm[a + \theta\{d + (1\text{-}\cos\omega t)\,mc^2E/eH^2\}] = \pm(a + \theta d')\ \text{say},$$

where $\omega = eH/mc$. The thickness of the layer at time t is d', as defined by (6); it varies periodically in the time $2\pi/\omega$. From (6) it is clear that the layer expands and contracts uniformly, each stratum dividing the layer in the same ratio θ throughout. Thus the electric field θE in the layer remains constant, as stated. The density Nd/d' of each layer remains uniform if it was so initially, but varies periodically. Besides the lateral expansion and contraction, the layer undergoes a longitudinal shearing motion, which varies periodically; the mean rate of shear is E/cH.

The values of d' and $2\pi/\omega$ are different for the two layers, being in the ratio of the masses of the charges. Thus the ionic layer pulsates with far greater amplitude, and much more slowly, than the electronic layer. Also the weaker the magnetic field H, the slower will be the pulsations of the layers and the greater their amplitudes.

2.3—If the slab, while possessing no mean motion, is a gas at temperature T, the particles within the neutral interior will spiral about the lines of magnetic force; the component of their motion transverse to $\mathbf{z}$

will rotate about $\mathbf{z}$ with the angular velocity ω, while their $\mathbf{Z}$-motion will remain constant except so far as it is changed by collisions. The charges near the planes $y = \pm a$, which are carried by their spiral motion into the charged layers, will be affected slightly by the electric field in these layers; and if the particles of the layers themselves also have random motion, the conditions in the two layers will not be quite so simple as those indicated above. But the layers will be stable, since any charge which, by its random motion, is carried beyond its fellows out of the layer, will be restored to the layer by the deflecting action of the field. The random motions slightly blur the simple conditions previously described, but without altering their character in any essential feature.

2.4—Next consider the slab with respect to axes in uniform motion relative to it, with the velocity $-u\mathbf{x}$, so that the slab itself becomes a slab-stream having the velocity $u\mathbf{x}$ relative to these axes. If u^2/c^2 is negligible compared with unity, as we suppose, the new values of the electric and magnetic intensities at a point where in the former case they were $\theta E\,\mathbf{y}$, $N\mathbf{z}$, now become

$$(\theta E + uH/c)\mathbf{y},\ (H + u\theta E/c)\mathbf{z}$$

Suppose that

$$u/c = -E/H \tag{7}$$

so that E must be considered small in comparison with H; then since in the former case the electric field was $E\mathbf{y}$ (corresponding to $\theta = 1$) everywhere outside the slab, it is now everywhere zero outside the slab-stream; inside the slab it was zero (corresponding to $\theta = 0$), so that inside the slab-stream it is $(uH/c)\mathbf{y}$. In the surface layers it varies uniformly from zero at the outer boundary to $(uH/c)\mathbf{y}$ at the inner one, being $(1-\theta)\,(uH/c)\mathbf{y}$ for the stratum θ. The magnetic field is everywhere approximately $H\,\mathbf{z}$, because the term $u\theta E/c$, which is zero outside the stream, $-(u^2/c^2)\theta H$ in the charged layers, and $-(u^2/c^2)H$ within the stream, is negligible in comparison with H; in fact, we have already neglected variations of $\mathbf{H}$ of this order by not considering the magnetic effect of the electric currents corresponding to the shearing motion of the layer. This will be considered in § 2.51.

2.5—Thus the former problem, referred to the new axes, gives the approximate solution for a uniform slab-stream moving with velocity $u\mathbf{x}$ in the presence of a magnetic field $H\mathbf{z}$, and in the absence of any external electric field. The slab will be polarized, having two surface-layers containing only charges of one sign; these are initially of thickness

$$d = uH/4\pi Nce \tag{8}$$

but pulsate so that at time t their thickness d' is given by

$$d' = d + (1-\cos\omega t)\,(mcu/eH), \tag{9}$$

where mcu/eH is taken positive whatever the sign of e; the paths of the particles of the layer are now trochoidal, the mean velocity in the stratum θ being $(1-\theta)u$, and the velocity of circular motion θu. Inside the slab, in the neutral region, the particles execute straight paths with velocity u, subject to the balanced forces $(uH/c)\,\mathbf{y}$ (electric) and $(-\,uH/c)\,\mathbf{y}$ (electromagnetic).

2.51—The variation of H, which, as already indicated in § 2.4, is only of the second order in u/c, will be oscillatory, since, in addition to their mean velocity $(1-\theta)u$ ($\equiv V$ say), the particles are endowed with

circular motion: the mean value of the variations of H may be obtained readily from the equations satisfied in the charged layers, where (alone) there is an electric current.

These equations are:

$$\delta H/\delta y = 4\pi NeV/c,\ \delta E/\delta y = 4\pi Ne,\ E = VH/c,$$

hence,
$$H\delta H/\delta y = 4\pi NeVH/c = E\ \delta E/\delta y$$

or,
$$\delta(H^2-E^2)/\delta y = 0$$

Thus, if H_0 is the value of H outside the stream (where $E = 0$) in the charged layers and within the stream $H^2 = H_0^2 + E^2$. Within the stream, therefore, $H^2 = H_0^2 + V^2H^2/c^2$ or $H = H_0\ (1-V^2/c^2)^{-1/2}$.

2.6 – If the gas is at a temperature of 6000°, as will be supposed in the subsequent work, the particles will possess random motions relative to the mean velocity of the stream; let V' denote the mean thermal velocity of the particles; V' for Ca-atoms, H-atoms, and electrons at a temperature of 6000°, is approximately 2×10^5, 10^6, and 5×10^7 cm/sec respectively. All of these are smaller than the values of u to be considered (10^8 to 10^9 cm/sec).

Corresponding to the spiral motions inside the stationary slab (§ 2.3), the internal particles of the slab-stream will have like spiral motions superposed on $u\mathbf{x}$; in the $\mathbf{x}$ direction the motion will always be forward, but fluctuating; there will also be a fluctuating transverse motion parallel to $\mathbf{y}$, and a random transverse motion parallel to $\mathbf{z}$ (steady except for collisions). These velocities superposed on $u\mathbf{x}$ are very slight compared with u for any kind of ions, and for them the velocity-vector will never deviate appreciably from the $\mathbf{x}$ direction; for the electrons the velocity-vector may be inclined considerably to the $\mathbf{x}$ direction, and steadily so (except for collisions) in the xz-plane. The maximum deviation of the paths from their mean rectilinear course (a straight line in the xz-plane) varies between $+ mcV'/eH$, which for $H = 1$ gauss, is only 3 cm for the electrons, and about 800 cm for Ca-atoms. These deviations may be compared with the corresponding ranges of pulsation of the charged surface-layers, which are mu/eH, that is for $H = 1$, about 6 cm for the electrons and 4×10^5 cm (4 km) for Ca-atoms, taking $u = 10^8$ cm/sec.

The random motions of the particles in the surface-layers will modify the ideal conditions described in § 2.5 to a similar degree, and therefore by amounts which, as regards displacements in the y-direction, are absolutely small for the electrons, and relatively small (compared with the thickness of the layer) for the ions. Thus the main features of the solution are unaffected by the random motions.

2.7 – It has been tacitly assumed that the stream has its equilibrium polarization from the outset of the problem. If there is no initial magnetic field in the presence of the slab-stream, and a slowly increasing uniform field is introduced, the polarization will be gradually set up; we have not thought it worth while to attempt to work out this very difficult problem in detail, because it seems clear that the conditions at any time will be approximately, though not exactly, the same as those already described for a constant field equal in strength to the actual field existing at this instant. Initially, the minimum thickness d of the charged layers is small, but the lateral pulsations are large and slow. The latter decrease, and become more rapid as the field increases

and, with it, the minimum thickness of the charged layers. If the field increases so slowly that the outer particles in the charged layers have time to get far away from the initial boundary of the stream during the slow initial pulsations, some of them may be left behind there, to spiral in paths of diminishing radius as the intensity of the field increases.

2.8—If the field H is increased somewhat beyond the value

$$H_0 \equiv (4\pi ce/u)\ ND \tag{10}$$

where D is the unpolarized thickness of the stream, the two sets of charges will be completely separated by the field, because the polarization displacement d, as given by (8), will exceed D. The charged layers will include all the ions (or all the electrons) in the stream, with no region of neutral gas between. The maximum electric field which their separation can produce is $E_0 \equiv 4\pi eND$, which is insufficient to balance the electro-magnetic deflecting force on the charges when $H > H_0$, at least if their velocity is $u\mathbf{x}$. Actually, as H increases from zero to H_0, the inner surfaces of the charged layers move laterally, subject to opposing electric forces, and the velocity and kinetic energy of their particles is reduced; thus the maximum electromagnetic force on these particles is less than uH/c, and a correspondingly smaller electric force suffices to balance it; therefore a value of H somewhat exceeding H_0 is necessary for complete separation of the charges. When the charged layers are separated, the mean velocity of the inner surface of each will be cE_0/H or $4\pi ceND/H$ or uH_0/H, while for the outer surface it remains zero as before. The inner surface, as well as the other strata of the layers, will pulsate, owing to the y-component of velocity acquired by the stratum while the polarization is being set up. The two layers will not move right away from one another, but will pulsate side by side, perhaps overlapping one another to some extent at certain stages during their pulsations.

2.9—The stream has been supposed to move transverse to the field, but it may also have a component of velocity parallel to the field. This component will remain constant, and the consequences of the motion transverse to the field, as discussed above, will not be affected.

3—*The motion of a cylindrical stream in a uniform magnetic field*

3.1—The next simplest form of stream to consider is an infinitely long cylinder of circular cross-section, in a uniform magnetic field. For simplicity, we suppose the stream to be already polarized by a displacement

$$d = uH/2\pi Nce \tag{11}$$

(half that in the case of the slab, which we shall assume to be small, either through uH being small or N large). This will produce an electric field that will balance the electromagnetic deflecting force inside the stream. But this case differs essentially from that of the slab in that there is now an electric field outside the stream, and the charged layer will tend to escape rapidly under the influence of this field.

3.2—Take the x- and z-axes, respectively, along the axis of the cylinder and parallel to the magnetic field; the initial surface density of charge at a point $y = a \cos\theta$, $z = a \sin\theta$, where a is the radius of the cylinder, will be $\sigma = -\sigma_0 \cos\theta$, σ_0 being the surface-density Ned, or $uH/2\pi c$ in the "equatorial" plane of the cylinder ($z = 0$). The

electric potential outside the cylinder will be $-2\pi\sigma_0(a^2/r)\cos\theta$; the r, θ components of the electric force will be equal to $-2\pi\sigma_0\,(a/r)^2\cos 2\theta$, $-2\pi\sigma_0\,(a/r)^2\sin 2\theta$. The latter will accelerate the surface-charges away from the plane $z = 0$, very nearly along the direction of the lines of magnetic force, while the transverse (y) electric force, in conjunction with $\mathbf{H}$, will merely cause a fluctuating shearing and pulsating motion in the charged layer. On account of the electric force outside the stream, the mean x-velocity in the charged layer, in the equatorial plane, will vary from $u\mathbf{x}$ on its inner surface to $-u\mathbf{x}$ on the outer one, instead of from $u\mathbf{x}$ to 0, as in the case of the slab.

3.3—The electrons forming the negatively charged layer ($y > 0$) will escape (in the $\pm z$-directions) much more rapidly than the ions, because while the former have much the smaller mass, the accelerating electric force is (at the beginning) the same for them as for the ions. They will therefore travel far beyond the latter, in equal times.

As charges escape from the surface, new charges will flow to it from the interior so as to maintain the internal field at the uniform value $(uH/c)\mathbf{y}$, just sufficient to balance the electromagnetic deflecting force. This corresponds with the fact that, relative to axes moving with the stream, the electric field inside it must be zero (to a high order of approximation), since the stream is a good electrical conductor. The internal field is due to the charges over the surface and those that have escaped from it.

3.4—The rapid escape of electrons from the half of the stream lying in the region $y > 0$ will leave behind, on or near the surface, an excess of positive charge. This will increase, and will slow down the electrons and increase the rate of escape of the ions, tending to equalize the rate of escape of the charges of opposite sign. If the steady state can be attained or approached, the rate of escape of ions and electrons across any plane $z = \text{constant}\ (>a)$ must be nearly equal. But, as will appear, the electrons on first leaving the surface have higher velocities than the ions, so that the number of the escaping charges between any two planes $z = z_1$, $z = z_2$ is greater for the ions than for the electrons. Hence the total charge between two such planes is positive except in the most distant regions where the electrons are that escaped first.

3.41—If we could regard the escaped charges as being too far away to affect the electric field inside the stream, this field, which has the value $(uH/c)\mathbf{y}$, would then be due to the surface-charge. The only way in which a uniform field can be produced inside a cylinder when the total surface-charge is not zero, is for the excess charge to be spread uniformly over the surface; the combined density σ of the distribution is then equal to $\sigma_+ - \sigma_0\cos\theta$, where σ_+ is the mean excess charge per unit area. The area over which the charge is negative is now greatly reduced, though not to zero (so that $\sigma_0 > \sigma_+$), because negative charge must still escape.

3.5—Actually the excess charge, here represented by σ_+, is spread over a larger volume, between the planes $y = \pm a$, outside the stream; it includes the escaping charge referred to in § 3.4. This outside charge is equivalent, so far as regards its capacity to affect the electrostatic field within the stream, to a *smaller* amount of charge on the surface, the reduction being greater, the more distant the situation of the external volume charge density. If we ignore this extension of the excess charge,

the z-component of the field outside the stream is altered approximately to the value

$$4\pi\sigma_+ \ (a/r) \sin\theta - 2\pi\sigma_0 \ (a/r)^2 \sin 2\theta, \tag{12}$$

which at the surface reduces to $4\pi\sigma \sin\theta$; it changes sign with σ, so that the force always impels the surface-charge (positive or negative) away from the stream. They will escape continuously in the $\pm z$-directions, remaining approximately between the planes $y = \pm a$. They will also have systematic motions in the x-direction, given by $c\mathbf{E}_\wedge\mathbf{H}/H^2$. As they move away from the plane $z = 0$, the corresponding values of r and θ (at least for $y > 0$) will increase. Since the second item in (12), which is negative for $y > 0$, decreases more rapidly than the first, (12) will become positive beyond a certain distance, and the electrons will gradually be retarded until their speed tends, from above, to the same limit as the increasing speed of the ions. At a great distance, they will both travel on together towards infinity with a finite speed. It may be noted that the neglect of the first-escaped electrons, in deriving (12), will be of increasing importance for large values of $\pm z$. This is evident from the fact that the potential of the field calculated from the surface distribution $\sigma_+ - \sigma_0 \cos\theta$ would contain the term $-4\pi\sigma_+ a \log r$, which is infinite at infinity. This is really balanced by an infinite term of like logarithmic order, due to the electrons that escaped first.

3.6 – The value of σ_+/σ_0 can be approximately deduced from calculations of the rate of escape of ions at the surface. The mean z-velocity of the charges in the first stage of their motion (up to a given small time, t_0 say) will be proportional to the acceleration in the z-direction, namely, E_z/m, where m denotes the mass (m_i or m_e), and E_z the z-component of the force at the surface given by (12), or $4\pi\sigma \sin\theta$. The rate at which the particles leave an element dS of the surface at a point (a, θ) is therefore proportional to $(1/m)\ \sigma^2 \sin\theta \,\mathrm{d}S$. The electron-layer ranges from $\theta = -\theta_0$ to $\theta = \theta_0$, where $\cos\theta_0 = \sigma_+/\sigma_0$. Hence the equation of equality of rate of escape of electrons and ions is

$$\frac{1}{m_e}\int_0^{\theta_0} \sigma^2 \sin\theta \,\mathrm{d}S = \frac{1}{m_i}\int_{\theta_0}^{\pi} \sigma^2 \sin\theta \,\mathrm{d}S; \tag{13}$$

on integration this gives

$$\frac{\sigma_0^3 - \sigma_+^3 - 3\ \sigma_0\sigma_+\ (\sigma_0 - \sigma_+)}{\sigma_0 + \sigma_+^3 + 3\ \sigma_0\sigma_+\ (\sigma_0 + \sigma_+)} = \frac{m_e}{m_i} \tag{14}$$

On putting $\sigma_+ = \sigma_0\ (1 - \epsilon)$, we get

$$\epsilon = 2\left(\frac{m_e}{m_i}\right)^{\frac{1}{3}} \Big/ \left\{ 1 + \left(\frac{m_e}{m_i}\right)^{\frac{1}{3}} \right\} \tag{15}$$

and since m_e/m_i is small, it follows that

$$\epsilon \equiv \frac{\sigma_0 - \sigma_+}{\sigma_0} = 2\left\{\frac{m_e}{m_i}\right\}^{\frac{1}{3}} \tag{16}$$

approximately. For hydrogen-ions this gives $\sigma_+/\sigma_0 = 0.86$, and θ_0 about 30°, while the maximum negative value of σ is about $(1/10)\ \sigma_0$ or one-twentieth the maximum positive value of σ. For heavier ions, σ_+/σ_0 will be still nearer to unity.

These estimates clearly depend only on m_e/m_i, and not on the size or density of the stream, or the intensity of the magnetic field.

It is evident that the electrons will still be accelerated much more than the ions, and will travel away with much higher velocities. Hence

heir volume-density after escape will be less than that of the ions, and s equal numbers of ions and electrons must cross any plane $z = z_1$, he number of ions between two planes must exceed that of the elecrons. Hence, as indicated in § 3.4, the σ_i-charge is really spread over great range of z, and not merely over the surface of the stream. This vill reduce the actual excess positive surface-charge on the stream. he electrons will be retarded after attaining a certain value of $\pm z$, hile the ions are being continually accelerated, until they and the lectrons finally reach a stage where they travel on side by side with qual speeds.

3.61·—The volume-density of the ions decreases as z increases, since hey are being accelerated. The converse reason indicates that for the lectrons the volume-density increases with z. The limiting volumeensities will be such that the number of ions and electrons between wo z-planes (for large values of z) are equal. The electrons will be more oncentrated than the ions because the breadth of the stream from hich they escape is less than for the ions, and moreover the latter will xecute larger spirals than the electrons, due to their thermal motions nd their original motion u**x**.

At large values of z the *mean* x-velocity of the ions and electrons ill be determined by the y-component of electric force there existing. his again will depend on the total charge of either sign per unit area n the xz-plane, the part of the field due to the surface charges over the ylinder probably being negligible in comparison with the local field.

3.7·—We have not attempted to make a definite calculation of the otion and density of the escaping charges, but have obtained an stimate of the limiting z-velocity as follows: The potential over a large urface beyond the outermost escaped charges must be zero. Between $= \pm a$, at points between the outermost electrons that escape first, nd the ions and electrons and ions that follow after, the potential ust be negative. At the surface of the stream, in the positively charged egion, the potential is positive. The ions and electrons that leave the urface of the cylinder do so with no initial z-component of velocity, nd ultimately (apart from the first set of electrons balanced by the $_+$ distribution) they attain the same z-velocity w_∞. In each case the inetic energy which they gain is equal to the change in their potential nergy between the two states. The change of kinetic energy for the ns is approximately $\frac{1}{2} m_i (w_\infty{}^2 + u_\infty{}^2 + v_\infty{}^2 - u^2)$, or approximately $m_i w_\infty{}^2$, since the change in the x- and y-components will be slight. imilarly for the electrons it is approximately $\frac{1}{2} m_e w_\infty{}^2$.

Let ϕ_-, ϕ_+ be the mean potentials over the respectively negative nd positive regions of surface-charge on the cylinder, and let $\phi_\infty{}'$ be e potential at a great distance in the $\pm z$-direction (between $y = \pm a$), ut on the nearer side of the set of electrons that escape first. Let ϕ_∞ e the potential far beyond this set of electrons. Then if ϕ_∞ is taken be zero, $\phi_\infty{}'$ will be negative, while ϕ_-, ϕ_+ will be respectively negative nd positive. Since approximately

$$\tfrac{1}{2} m_i w_\infty{}^2 = e (\phi_+ - \phi_\infty{}'), \quad \tfrac{1}{2} m_e w_\infty{}^2 = -e (\phi_- - \phi_\infty{}')$$

follows that

$$\frac{-\phi_- + \phi_\infty{}'}{\phi_+ - \phi_\infty{}'} = \frac{m_e}{m_i} \qquad \text{.7)}$$

onsequently ϕ_- is nearly equal to, but numerically rather greater than,

ϕ_∞', and $\phi_+ - \phi_\infty'$ is therefore approximately equal to $\phi_+ - \phi_-$. The determination of this difference is uninfluenced by the σ_+ distribution, and therefore only the distribution $-\sigma_0 \cos\theta$ need be considered. On averaging over the arcs from 0 to θ_0 and θ_0 to π, this leads to the approximate value $4\sigma_0 a$ for $\phi_+ - \phi_-$. Consequently

$$\tfrac{1}{2} m_i w_\infty^2 = 4ea\sigma_0$$

or

$$w_\infty = 4\sqrt{(\sigma_0 ea/2m_i)} = 4\sqrt{(aeuH/\pi cm_i)} \tag{18}$$

It should be noted that this is independent of the density of the stream.

For a very large stream w_∞ may be considerable, even in a weak field. For example, suppose $u = 10^8$ cm/sec, $a = 10^{12}$ cm (the value estimated by Chapman for solar streams at the Earth's distance) and $H = 10^{-6}$ gauss or 0.1γ, the intensity which exists at a distance of 45 Earth-radii, or about 3×10^{10} cm, from the Earth's centre; then for hydrogen-ions, $w_\infty = 10^9$ cm/sec approximately. This calculation has no immediate application to the case of the Earth, however, because the stream-width is much greater than the distance from the Earth's centre and the field over the stream would be anything but uniform. For this reason also it is doubtful whether it is worth while to attempt to find the volume-density of the escaping sets of charges in the above problem. This density is of interest for auroral theory, and it seems likely that it will not be greater than the number density of the stream itself (N), and may be very much less. One method of calculation suggests that its order of magnitude will be that of uH/eac when this does not exceed N; with the above values of u, a, H, this is about 10^{-11}.

In a non-uniform field like that of the Earth, where there is strong convergence of the lines of force, along which the escaping charges travel, an initially small density may be much increased by this cause. But the detailed consideration of the auroral aspects of our problem is deferred to a later communication.

3.8—It seems likely that the cylindrical stream will continue to emit electrons and ions at its surface until it becomes completely dispersed, tending, in fact, to become a polarized infinite slab-stream in which, besides the forward motion, there is also a non-uniform distribution of motion in the z-direction. The energy of the z-motion of the escaping charge will be supplied at the expense of the kinetic energy of the forward motion of the stream, so that the particles in the interior will be continually (though probably slowly) retarded, whilst the rate of escape of charges from the surface will gradually diminish.

The sequence of events in the case of a collection of ions and electrons streaming transverse to the field, in the form of a cylinder of *any* cross-section, is likely to be similar in all essentials to those here described for a circular cylinder.

4—*The motion of a neutral ionized system of any form in a uniform magnetic field*

4.1—Any uniform neutral system of N ions and N electrons per unit volume, moving with a uniform velocity $\mathbf{V}$ in a uniform magnetic field $\mathbf{H}$, will become polarized by a relative displacement $\mathbf{dr}$ of the ions and electrons, such as will set up a uniform electric field $\mathbf{E} = -(1/c)\,\mathbf{V} \wedge \mathbf{H}$ almost exactly, within the system, whatever its outer form.

This field will balance the electromagnetic deflecting force on the charges, which will therefore move (almost exactly) along rectilinear paths. The displacements of the ions and electrons relative to their undisturbed paths (that is, their paths in the absence of the magnetic field) will be approximately inversely proportional to their masses, so that the relative motion will be nearly wholly due to the electrons. The polarization **P** is given by $N e \mathbf{dr}$; it will depend on the outer form of the system, but not on the size, and in general will vary in magnitude and direction from point to point; but in three simple special cases it is uniform. These correspond to the outer forms (*a*) an infinite-plane slab, for which $P = \frac{1}{4\pi c} \mathbf{V}_\wedge \mathbf{H}$, (*b*) an infinite circular cylinder, for which $\mathbf{P} = (1/2\pi c)\,\mathbf{V}_\wedge \mathbf{H}$ and (*c*) a sphere, for which $P = (E/4\pi c)\,\mathbf{V}_\wedge \mathbf{H}$. It is here supposed that **dr** is small and that the surface-charge, which will be the component (P_n) of **P** normal to the surface, has not had time to be dispersed by its mutual repulsion.

The volume-distribution of charge will be zero in all cases, since the electric field is uniform. The surface-distribution of charge (necessary to produce this electric field **E**) will be the same as that induced on a conductor of the same shape as the stream by an external field $(1/c)$ $\mathbf{V}_\wedge \mathbf{H}$.

4.2.—Except in the case of the infinite-plane slab, the surface-charge is repelled from the surface, and more rapidly from the negatively charged area than from the positive, until the system has acquired, by this process, an excess positive charge, thus enlarging the positive surface area at the expense of the negative. The dispersed surface-charge is, however, continually replaced by the motion of charges (mainly of electrons) to or from the surface, so as to maintain the internal field almost exactly at the value $-(1/c)\,\mathbf{V}_\wedge \mathbf{H}$. The difference between **E** and this value must be such as will produce the necessary flow of the electrons to maintain the surface-charge.

4.3.—The three special cases in which **P** is known suggest that, in general, the order of magnitude of **P** is $(1/2\pi c)\,\mathbf{V}_\wedge \mathbf{H}$, so that **dr** will be of the order of $(1/2\pi c N e)\,\mathbf{V}_\wedge \mathbf{H}$. This is greatest when **V** is perpendicular to **H**, and then dr is of the order $VH/2\pi c N e$, or approximately $VH/90N$. Thus taking $H = 0.35$, the surface-value at the Earth's equator, and $V = 10^8$, $dr = 4 \times 10^5/N$, so that if $N > 0.1$, $dr < 40$ km; this is very small compared with the Earth's dimensions.

4.4.—If the magnetic field, though remaining uniform, changes with time, the stream will remain approximately in the steady state, provided that the rate of change of the field is not too large. The exactness with which the field E is likely to balance the electromagnetic force on the charge may be illustrated by determining the time required for the displacement dr to be produced, supposing that **E** falls short of the exact balancing field $-(1/c)\,\mathbf{V}_\wedge \mathbf{H}$ by a fraction f, necessary to produce the required change in polarization. The transverse acceleration of the electrons is then $feVH/m_e c$, where m_e denotes the electronic mass. The corresponding time δt required for the transverse displacement dr is given by

$$(\delta t)^2 = 2\, m_e c\, dr/fe\, VH = m_e/f\pi e^2\, N, \tag{19}$$

on substituting for dr from § 4.3.

Inserting numerical values, this gives $\delta t = 3.5 \times 10^{-5}/\sqrt{(f\ N)}$ so that if, for example, $f = 1/1000$, and $N = 0.1$, then $\delta t = 3.5 \times 10^{-3}$ sec. If this time is small compared with that during which the intensity of the field H alters in a sensible ratio, the stream will approximately take up the "equilibrium" state at every instant.

4.5—If the field, instead of being uniform, increases in intensity in the direction of motion, then it may be possible for a steady state to be set up as in § 4.4. In this case the displacement dr appropriate to each point will increase as the stream advances, and the deflecting force will likewise increase; the value f of the unbalanced fraction of this force will adjust itself so that the "equilibrium" value of dr is nearly attained at each point. This requires that the distance traversed during the interval δt in the direction of the stream, namely, $3.5 \times 10^{-5}V/\sqrt{(fN)}$, shall be small compared with that over which the intensity of the field H alters in a sensible ratio. In the Earth's field, H varies as $1/r^3$, so that a change of 10 per cent in H is attained when r changes by about 3 per cent. This distance is least near the Earth's surface. Three per cent of the Earth's radius is 2×10^7 cm or 200 km, which is certainly large compared with $3.5 \times 10^{-5}V/\sqrt{(fN)}$ cm even if (when $N = 0.1$ and $V = 10^8$ cm/sec), f is 10^{-6}. Only if N were very much less than 0.1, that is, for an extremely rare stream, would the unbalanced fraction of the deflecting force have to be other than small, in order to provide the equilibrium polarization by deflection of the electrons. But when N is very small, dr is correspondingly large, and the conception of the displacement as constituting a polarization ceases to have value. It seems probable, as will appear later, that such rare streams will have no appreciable effect upon the Earth's magnetic field.

4.6—In the preceding discussion the field has, in the main, been supposed constant as well as uniform, and the polarization has been supposed established from the outset. But if the field is slowly increased from zero, or if the stream advances into regions of gradually increasing intensity, the polarization is set up gradually. One effect of this is to retard the stream. The order of magnitude of the retardation can be calculated from the principle of conservation of energy. The polarization sets up an electric field of intensity $(1/c)\ \mathbf{V} \wedge \mathbf{H}$, with which is associated electrostatic energy of amount $E^2/8\pi$ or $V^2H^2/8\pi c^2$ per unit volume; it also increases the intensity of the magnetic field, for, as has been shown in § 2.51, $H^2 = H_0^2 + V^2H_0^2/c^2$, approximately, inside the stream. The increase in magnetic energy $(H^2 - H_0^2)/8\pi$ is therefore the same as the electrostatic energy. The total increase in the field-energy, $V^2H^2/4\pi c^2$ per unit volume, must be drawn from the kinetic energy of the stream, which is therefore reduced in velocity from (say) V' to V, where

$$\rho\ (V'^2 - V^2) = V^2\ H^2/4\pi c^2, \tag{20}$$

ρ being the mass-density of the stream.

Hence

$$(V/V')^2 = \lambda/(1 + \lambda) \tag{21}$$

where

$$\lambda = 4\pi\rho c^2/H^2 \tag{22}$$

This formula for the retardation is similar to one already given by Chapman,[19] which was obtained by considering the reaction of the magnetic field upon the transverse currents that set up the increasing polarization.

The following table indicates how the retardation varies with λ. The corresponding values of ρ, taking $H = 0.35$ (the surface-value at the Earth's equator), are also given. For smaller values of H, ρ for any given value of λ is reduced in proportion to H^2.

λ	$\frac{1}{100}$	$\frac{1}{10}$	$\frac{1}{5}$	1	2	10	100
ρ	1.07×10^{-25}	1.07×10^{-24}	2.13×10^{-24}	1.07×10^{-32}	2.13×10^{-23}	1.07×10^{-22}	1.07×10^{-21}
V/V'	0.10	0.30	0.41	0.71	0.82	0.95	1.00

It may be noted that a stream containing one hydrogen atomic ion (and one electron) per cc would have a density of 2.1×10^{-24} gm/cc. Such a stream would be considerably retarded in traveling into a field of intensity 0.35. The retardation becomes small, however, for streams of density corresponding to $50H^+$ ions (or about 1 Ca^+ ion) per cc.

4.7.—So far it has been supposed that the velocity of the stream is uniform throughout the stream, so that in general a steady state could approximately be set up. But if the velocity of the stream is not uniform, such a steady state cannot be set up, even in a uniform magnetic field, unless or until the velocity of the stream can be rendered uniform. The reason for this is that the deflecting force acting on the charges, namely, $(1/c)\ \mathbf{V}_\wedge \mathbf{H}$, will not be derived from a potential, so that no distribution of electric charges could produce the balancing electrostatic field necessary for a steady state. This case arises, for example, in the motion of an infinite cylindrical stream in a uniform magnetic field when the velocity of the stream varies in the direction of the field. Provided the density is not too low, electric currents will then flow across the cylinder, which will be acted on by the magnetic field. The main body of the stream will thus be accelerated in some parts and retarded in others, in a manner tending to make the velocity uniform throughout the stream.

-The internal steady motion of a neutral ionized stream in a non-uniform magnetic field

5.1.—The next problem to be discussed is the one already considered by Chapman,[19] namely, the internal *steady* motion of a neutral ionized stream in a *non-uniform* magnetic field. The region over which the latter extends (that is, over which the charges in the stream are deflected appreciably by the field) is supposed small compared with the lateral dimensions of the stream. The latter is supposed infinite along the direction of motion, the charges moving almost exactly along parallel straight lines, except in the region of the field.

The discussion of the problem at this stage is in accordance with the sequence of argument in this paper, though, as will appear, the important magnetic effects of the stream directed towards the Earth are phenomena of the initial stages, and not of the possible final steady state.

The difficulty of determining such a steady state is almost insuperable, the problem being, in fact, far more complicated than that of the *approach* of the stream towards the magnetic system, and here we shall only make some general remarks as to the nature of the solution.

It is obvious that if the stream is so rare that at any instant comparatively few charges (ions and electrons) are within the whole region of the field, their motions will be practically independent of one another, and approximately the same as those of a solitary charge, such as is considered in Störmer's researches. This is one extreme case; the other is that in which the electromagnetic deflection by the field is confined within narrow limits by the internal electrostatic field set up by the deflection itself, and also by the interaction of the charges between themselves. This second extreme case does not require a large density, $N = 0.1$ being amply sufficient for a stream moving with a velocity of 10^8 cm/sec in a field such as the Earth's (§ 4.5).

5.2—It might be supposed that in such cases the stream can become polarized at each point—a hypothesis that suggests itself by analogy with the simpler cases considered in §§ 2-4 and which, in fact, was assumed by Chapman in his investigation; but on closer examination this hypothesis proves to be untenable in the general case.

The assumption that the stream is polarized implies that the two sets of opposite charges in any small volume-element of the stream move approximately together. On account of the high mobility of the charges, this requires that the electric field **E** should balance almost exactly the magnetic deflecting force acting on the charges, which may be approximately taken as $(1/c)\mathbf{V}_\wedge \mathbf{H}$, ($V$ being the mean velocity of the charges in the element), unless this be vanishingly small. The electric field will therefore be independent of the density (N) of the stream, except in so far as this may affect the variation of **V**. Since the polarization **P** must produce this field, **P** will likewise be nearly independent of N.

By the principle of conservation of energy, the electromagnetic energy produced in setting up the polarization of the stream must be supplied by the mechanical or kinetic energy of the stream itself. The stream would therefore be retarded, the retardation being greatest in the strongest regions of the magnetic field. But since the polarization is independent of N, it is clear that a sufficiently dense stream would hardly be retarded at all. For a stream moving with velocity 10^8 cm/sec in the Earth's magnetic field, it would be sufficient for N to exceed a density of 10^{-22} gm/cc (corresponding to about 50 H or 1 Ca-atom per cc), to judge from § 4.6. Similar reasoning shows that the bending of such streams by the magnetic field would be exceedingly small, since the currents, due to the polarization, would be independent of N. Thus in a dense stream (such as has just been considered) the charges would move approximately along their undisturbed paths; and this leads at once to an inconsistency unless the interior of the stream can be shielded from the magnetic field. For the electric field, as we have seen, must be approximately equal to $(1/c)\ \mathbf{V}_\wedge \mathbf{H}$, and in the particular case of a steady state it must satisfy the condition $\mathbf{cur}\ \mathbf{E} = 0$. Since **V** is approximately uniform, and since $\operatorname{div} \mathbf{H} = 0$, this reduces very nearly to the condition

$$(\mathbf{V}.\ \mathbf{grad})\ \mathbf{H} = 0,$$

or

$$\delta\mathbf{H}/\delta s = 0,$$

where $\delta/\delta s$ denotes differentiation in the direction of **V**. This requires that **H** is uniform along any stream-line. But **H** tends to zero at large

stances, hence it must vanish at all points in the stream; but this is ntrary to the initial hypothesis that H exists and polarizes the stream. hus we must abandon the hypothesis for the most likely case of all hat of a dense stream) and so also in general—always, in fact, except r very special cases, such as those considered in §§ 2-4, where $\delta H/\delta s$ 0, because H is uniform throughout the stream.

5.3—The only alternative is to suppose that a system of steady rrents flows within the stream, their distribution and intensity de- nding mainly on the external field and the velocity and density of e stream. They may or may not shield the interior from the external agnetic system.

In any actual stream, however, the mutual interaction of the charges ould have to be taken into account (except for the extreme case already ferred to). If the stream be sufficiently dense, the conditions would much the same as those of a compressible conducting medium. This ould be the next simplest case to consider, since in the interior of any otropic conductor the volume-density of charge is vanishingly small. he electrostatic field within such a stream would be negligible, and the rrent density at any point would be proportional to, and in the direc- on of, the electromotive force $\mathbf{V}_\wedge \mathbf{H}$ (in e.m.u.) produced by the motion the stream in the magnetic field. It is supposed that the positive nd negative charges move with nearly (though not quite) the same elocity V, which requires the density to exceed some very small lower mit.

The conductivity of the stream is independent of its density, so at the current is proportional to $\mathbf{V}_\wedge \mathbf{H}$, the same for all densities ove the lower limit mentioned (except so far as the changes in V epend on the density). The reaction of the field on the current would nd the stream except in those regions where $\mathbf{V}$ and $\mathbf{H}$ are in the same irection. The force tending to produce bending is nearly independent the density, and hence the bending itself will be nearly inversely roportional to the density.

It can be verified that the tendency would be for the stream to onverge towards the poles of the magnetic system, and that the flow f currents would be such as to diminish the magnetic field in the regions here the stream moves towards the magnetic system, possibly dimin- hing the field over the magnetic system also. In the further regions here the stream moves away from the system, the magnetic field ould be increased somewhat, decreasing steadily to zero at infinite istance.

In the case of streams whose conductivity is not isotropic (for ex- mple, in a stream whose conductivity in the direction normal to the agnetic field is reduced because of spiral motion of the charges between ollisions), it would be possible for a volume-distribution of charge to e set up within the interior. The problem in this case is thereby com- licated still further; but fortunately in the theory here being developed he importance of the problem of the steady state is not sufficient to equire a detailed investigation of it at present.

(To be continued)

NOTES

(See also pages 132 and 149)

9. *American Geophysical Union*—The twelfth annual meetings of the American Geophysical Union and its sections were held in Washington, D. C., April 30 and May 1, 1931. In conjunction with the six original sections of the Union, the recently organized Section of Hydrology held its first meeting, at which 11 important papers were presented and much interest and enthusiasm were manifested.

There were 13 papers presented before the Section of Terrestrial Magnetism and Electricity at its meeting on April 30, as follows: D. L. Hazard, Magnetic work of the Coast and Geodetic Survey; J. A. Fleming, Field and laboratory investigations of the Carnegie Institution of Washington; G. W. Pickard and G. W. Kenrick, Recent developments in radio transmission measurements; Watson Davis, The URSI cosmic radio broadcast; H. W. Fisk, Reports to the Secretary of work by other organizations; H. D. Harradon, Proceedings of the Section of Terrestrial Magnetism and Electricity, Stockholm Assembly of the International Union of Geodesy and Geophysics; H. T. Stetson, Investigations at the Perkins Observatory of changes in the Kennelly-Heaviside layer as a function of lunar altitudes; J. Bartels, Use of magnetic data for investigating radiation from the Sun; R. Gunn, The electrical state of the Sun; H. B. Maris, Ultraviolet-light theory of comet activity; W. J. Peters, Magnetic observations on a moving ice-floe; H. W. Fisk, Isomagnetic charts of the arctic area; O. H. Gish, Significance of geoelectric data from polar regions. Another paper by H. B. Maris, A proposed Fort Conger magnetic and meteorological program, had to be omitted for lack of time, but it will be published in the Transactions of the meeting.

Of the five resolutions adopted at the General Meeting of the Union, four are of interest to the readers of the JOURNAL, as follows: (1) A resolution recognizing in Major-General Adolphus W. Greely, retired, the leader of the Lady Franklin Bay Expedition, 1882-1883, of the First International Polar Year, the outstanding figure in arctic exploration on this continent, and in recording its high appreciation of General Greely's contributions to our knowledge, the Union expressed its earnest wishes for the long continuance of his good health. (2) A resolution endorsing a plan of the Commission of the International Union of Geodesy and Geophysics for the Study of Tidal Waves, and recommending the participation by organizations and individuals in the United States in studying tidal waves and the phenomena connected with them, and further authorizing the appointment of one member each from the sections of Seismology and Oceanography to serve as a committee for developing a plan for such participation. (3) A resolution endorsing a plan indicated by the Director of the Central Seismological Bureau of Strasbourg, France, of making direct comparisons of new types of seismological instruments developed in the United States with the various types developed in Europe and (4) a resolution recommending to the Navy Department that it give thought to the question of continuing its work on gravity at sea and of securing the necessary soundings to supplement such work, especially in the waters of the West Indies, including the Caribbean Sea.

10. *Bulletins on the Physics of the Earth*—In order to give wider attention to research in the so-called middle-ground sciences, of which geophysics is a conspicuous instance, the United States National Research Council, through a number of especially appointed committees, is issuing a series of bulletins on the Physics of the Earth. The purpose of these bulletins is "to give the reader, presumably a scientist but not a specialist in the subject, an idea of its present status, together with a fore-looking summary of its outstanding problems." Thus far three of these bulletins have appeared, namely: (1) Volcanology, (2) Figure of the Earth, and (3) Meteorology. Further bulletins dealing with the following subjects are in preparation and will be issued when ready, without any particular regard to sequence: Gravity, deflection of the vertical, and isostasy; tides, ocean and Earth; variation of latitude; seismology; terrestrial magnetism and electricity; the age of the Earth; field-methods for detecting unhomogeneities in the Earth's crust; internal constitution of the Earth; oceanography.

A PHOTOGRAPHIC METHOD OF CHANGING THE RATIO OF ORDINATE-SCALE TO ABSCISSA-SCALE

By William J. Peters and J. W. Green

Abstract;—This method is proposed for the purpose of reproducing magnetograms or other continuous photographic records made at different observatories on the same scales as regards both time and value of magnetic or other recorded element with all the minutiae of detail. Two photographic exposures are made, one of the photographic record, the second of the resulting negative. In both exposures the sensitized paper is inclined at predetermined angles which depend upon the magnifications required of the abscissae and ordinates, respectively, and upon the condition that the respective scales be uniform throughout the final positive. Theoretically there is no limit to the choice of ratio desired between the scale of ordinate and the scale of abscissa. Practically the limit is fixed by the depth of focus available, and the smallest stop usable, or by the number of repetitions of the operation of two exposures. Experiments were made in which the final ordinates were made about three times as long as the original with respect to the abscissae in the one operation of two exposures.

In attempting to correlate the traces of magnetic storms, perturbations, or variations as registered at the different observatories, it is often desirable to have the traces on the same scale for direct visual comparing or for superposing. Drawing of traces free-hand to the same scale even with the use of coördinate paper prepared for the various scales is a long and tedious operation, and the result is satisfactory only for investigations in which the details are of no significance. As regards the abscissa- or time-scales of magnetograms, there is no difficulty in reproducing to one standard scale by the ordinary enlarging process of photography if the record is well defined, especially as many records are made on one of two time-scales, either 2 cm to the hour or 1.5 cm. On the other hand, scale-values for ordinates vary not only with different observatories, but also at any one observatory with varying local conditions. If, however, the ordinate-scale can be regarded as constant for each magnetogram, then it can be changed independently of the abscissa-scale by the following photographic process:

Two photographic exposures are made. In the first, the plane of the flat object AB, Figure 1—a magnetogram, for instance—is perpendicular to the optical axis OO_1 as usual, but with the sensitized paper A_1B_1 for the image, inclined at an angle a_{I} to the optical axis OO_1 about an axis indicated as end on, at O_1 in the plane of the film, perpendicular to the optical axis and parallel to the abscissae of the magnetogram. From this exposure a photographic negative is obtained. The second exposure is made with this negative A_1B_1 as object perpendicular to the optical axis O_1O_2 while the sensitized paper A_2B_2 is inclined as before, but through an angle a_{II}. This second exposure yields a positive with lengthened ordinates free from all perspective effects.

In actual manipulation the lens L remains fixed and the negative A_1B_1 is transferred to the plane AB, shifted if necessary to change the abscissa-scale along the optical axis to distances determined by equations (7) to (10). In the figure it has been found convenient to continue the drawing of rays, etc., from A_1B_1 and shift the lens and optical axis accordingly. This convention in the figure shows more clearly the necessity of making the axis, indicated end on at O_1, of the developed

negative coincide with the abscissa indicated end on at O in transferring for the second exposure.

The process thus described increases the ratio of ordinate-scale to abscissa-scale. Decreasing the ratio is accomplished by reversing the process; that is, by inclining the object on angle a_{II} and making the

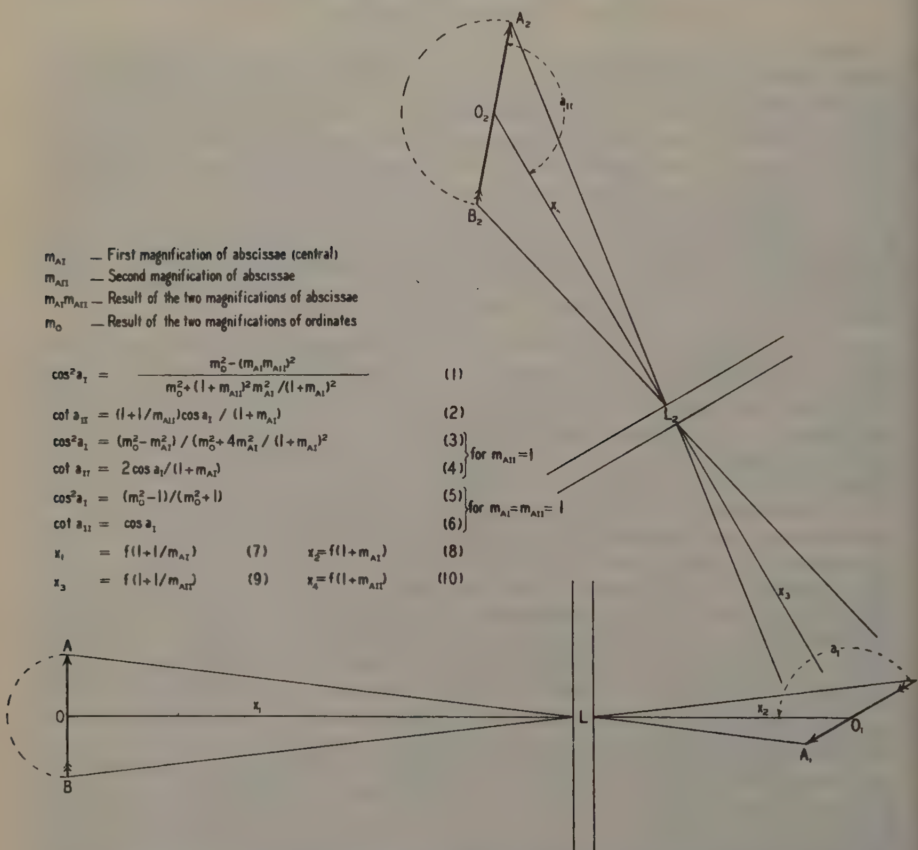

Fig. 1—Diagrammatical sketch illustrating geometric conditions in photographic method for changing ratio of ordinate to abscissa

image perpendicular to the optical axis in the first exposure, and then inclining the negative, as an object, on angle a_I with the second image perpendicular to the optical axis.

The angles a_I and a_{II} depend, for the same lens, only on the required magnifications or reductions of ordinates and abscissae. The relations are expressed by equations (1) to (6) of Figure 1, in which the total magnification of ordinates in the two exposures is denoted by m_O and the separate magnifications of abscissae in the first and second exposures by m_{AI} and m_{AII}, respectively.

The equation for a_I is quadratic and an imaginary value indicates that the operations must be performed in the reverse order.

The general equations (1) and (2) given in Figure 1 are derived from e triangles of the figure as follows:

$$\overline{O_1A_1} = \overline{O_1L} \times \overline{OA}/(\overline{OL} \times \sin a_I + \overline{OA} \times \cos a_I) \tag{11}$$
$$\overline{O_1B_1} = \overline{O_1L} \times \overline{OB}/(\overline{OL} \times \sin a_I - \overline{OB} \times \cos a_I) \tag{12}$$
$$\overline{O_2A_2} = \overline{O_2L_2} \times \overline{O_1A_1}/(\overline{O_1L_2} \times \sin a_{II} - \overline{O_1A_1} \times \cos a_{II}) \tag{13}$$
$$\overline{O_2B_2} = \overline{O_2L_2} \times \overline{O_1B_1}/(\overline{O_1L_2} \times \sin a_{II} + \overline{O_1B_1} \times \cos a_{II}) \tag{14}$$

ubstituting the values of $\overline{O_1A_1}$ and $\overline{O_1B_1}$ given by (11) and (12) in (13) nd (14), respectively, the latter become

$$\overline{O_2A_2} = \overline{O_1L}\times\overline{OA}\times\overline{O_2L_2}/(\overline{OL}\times\overline{O_1L_2}\times \sin a_I \sin a_{II} + \overline{O_1L_2}\times\overline{OA}\times \cos a_I \sin a_{II} - \overline{O_1L}\times\overline{OA}\times \cos a_{II}) \tag{15}$$
$$\overline{O_2B_2} = \overline{O_1L}\times\overline{OB}\times\overline{O_2L_2}/(\overline{OL}\times\overline{O_1L_2}\times \sin a_I \sin a_{II} - \overline{O_1L_2}\times\overline{OB}\times \cos a_I \sin a_{II} + \overline{O_1L}\times\overline{OB}\times \cos a_{II}) \tag{16}$$

If according to the conditions of the problem $\overline{OA} = \overline{OB}$ and $O_2A_2 =$ B_2, then equations (15) and (16) become equal, which can be true nly when

$$\overline{O_1L_2}\times \overline{OA} \times \cos a_I \sin a_{II} - \overline{O_1L} \times \overline{OA} \times \cos a_{II} = 0 \tag{17}$$

hence with transformations indicated by the Figure 1 and equations) and (9)

$$\cot a_{II} = \overline{O_1L_2}\times \cos a_I / \overline{O_1L} = x_3 \cos a_I / x_2 = (1+1/m_{AII}) \cos a_I / (1+m_{AI}) \tag{2}$$

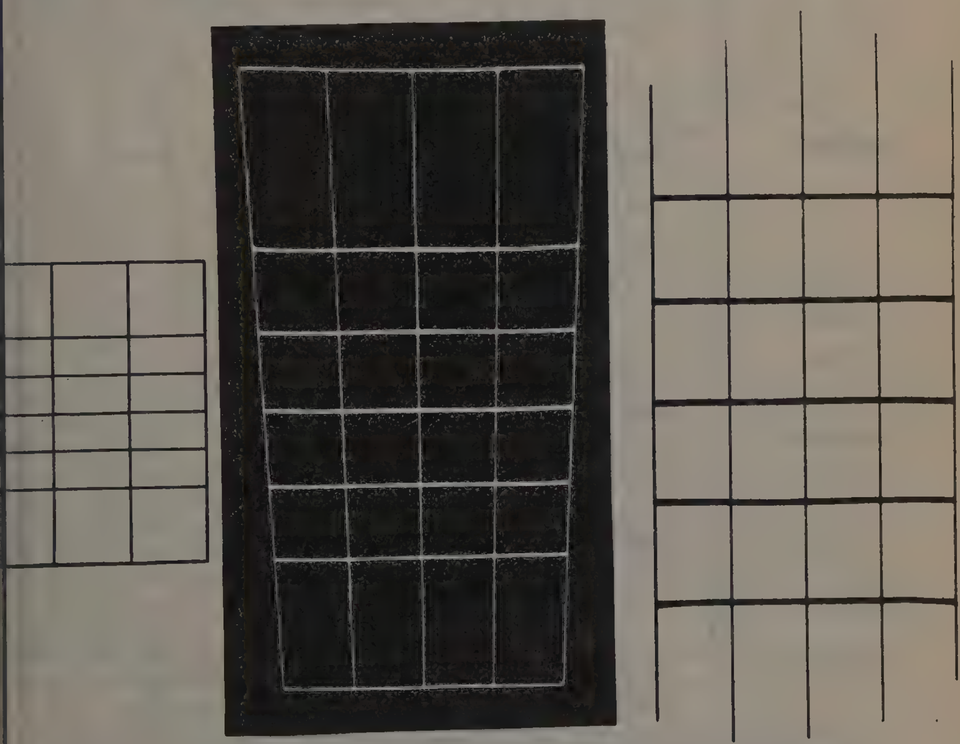

FIG. 2—Test of practicability of method using accurately drawn rectangular grid

Also since $m_O = O_2A_2/OA$ or O_2B_2/OB, $O_1L/OL = m_{AI}$ and $O_2L_2/O_1L_2 = m_{AII}$, equations (15) or (16), in view of equation (17), give

$$1/m_O^2 = (1 - \cos^2 a_I)\ (1 - \cos^2 a_{II})/m_{AI}^2 \times m_{AII}^2$$

from which

$$\cos^2 a_I = \frac{m_O^2 - m_{AI}^2\ m_{AII}^2}{m_O^2 + (1 + m_{AII})^2\ m_{AI}^2/(1 + m_{AI})^2} \qquad (1)$$

If the abscissae of a number of graphs are to be reduced in some fixed ratio the equations for a_I and a_{II} reduce to very simple expressions. Suppose the time-scale of a lot of magnetograms is to be reduced one-half and the various scales of ordinates to some arbitrary standard, then

$$\cos^2 a_I = (m_O^2 - 0.25)/(m_O^2 + 0.444)$$
$$\cot a_{II} = 4/3 \cos a_I$$

Other simplifying conditions are indicated in the equations of Figure 1.

Figure 2 shows a rectangular grid accurately drawn to test the practicability of the method. The negative obtained from the first exposure

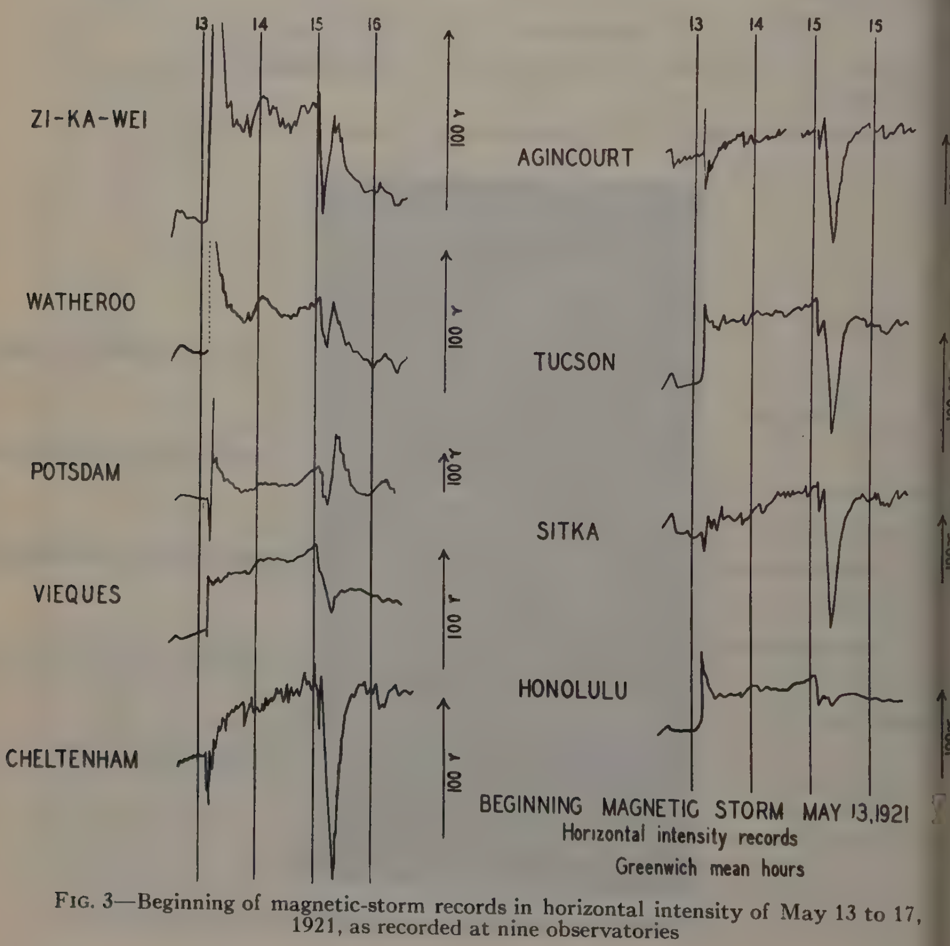

FIG. 3—Beginning of magnetic-storm records in horizontal intensity of May 13 to 17, 1921, as recorded at nine observatories

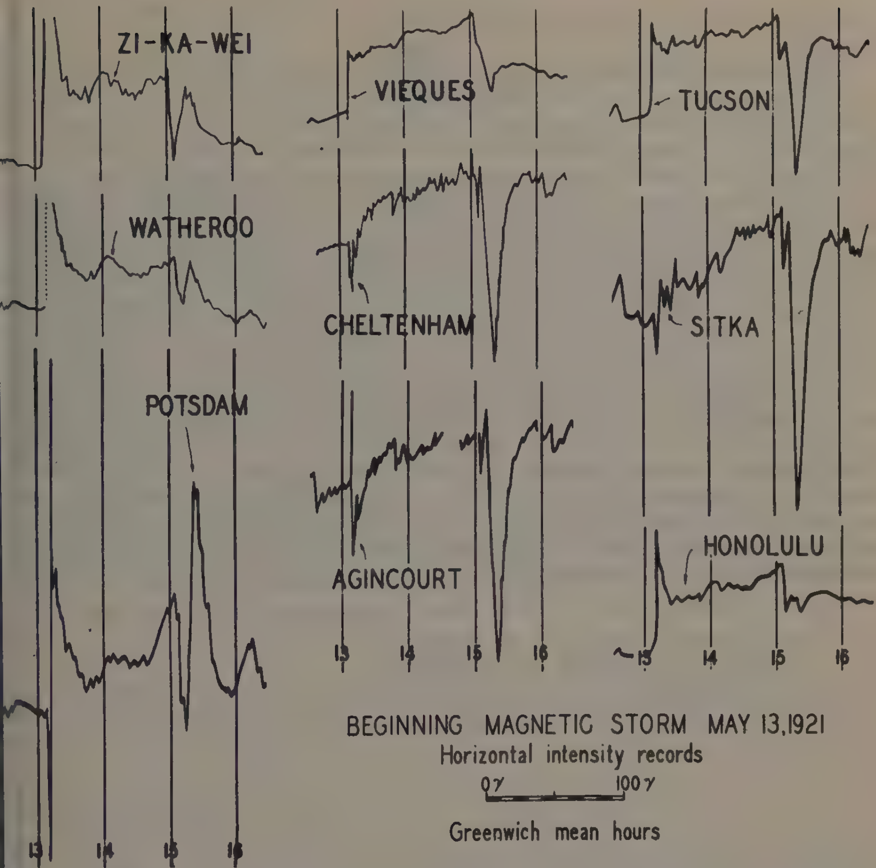

FIG. 4--Beginning of magnetic-storm records in horizontal intensity of May 13 to 17, 1921, as recorded at nine observatories, photographically reduced to equivalent time- and ordinate-scale

was made at an inclination of 30° to the optical axis and the final positive made at an inclination of 48°.5.

For the purpose of trying out the method on different curves, there were available tracings of curves of horizontal intensity of nine observatories, which had been made for a study of the beginning of the magnetic storm of May 13, 1921. These are shown in Figures 3 and 4, with their reproductions on one uniform scale. The time-scale was the same for all. The scales of horizontal intensity for the original tracings are given by the length of the arrows which represent 100 gammas. These scales varied from 14 mm at Potsdam to 50 mm at Watheroo per 100 gammas.

The crude apparatus of these experiments consisted of cardboard boxes, wooden stands, etc. The lens used was a Bausch and Lomb process lens of about 13-inch or 33-cm equivalent focus.

The width of the traces is broadened by the process of elongating the ordinates. The definition of the extreme regions of the exposures

depends upon the depth of focus of the lens, the inclinations, and the stop.

The least inclination used in the experiments was 26°.5 for the Potsdam curve. This inclination, necessary to increase the scale of ordinates three times, is probably the limit compatible with good definition, and a stop that required about four minutes' exposure. Of course, the ratio of three can be increased by repeating the whole process.

Two other photographic methods have been suggested for changing the ratio of ordinate-scale to abscissa-scale. One suggested by M. Goldberg is a variation of pin-hole photography in which the pin-hole is replaced by two mutually perpendicular slits. The ratio required is obtained by a proper separation of the two slits along the optical axis. The other method suggested by L. B. Tuckerman, of the Bureau of Standards, is a slight modification of the method which has been used to photograph the entire surface of a cylinder in one exposure by rotating the object and sliding the film at the same speed. The ratio required could be obtained by using different speeds with proper direct magnification. In both methods one exposure is made. For the reproduction of magnetograms, however, the time-exposure necessary to secure the required detail would be very long. The two exposures necessary in the method given in this paper also have the advantage that the other curves of the magnetograms may be obliterated on the first negative.

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DEPENDENCE OF THE NORMAL EARTH-CURRENT ON LATITUDE

By David Stenquist

At the Stockholm meeting last August I submitted to the Section of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics a paper[1] containing also an investigation of the diurnal variation (inequality) of the earth-current as a function of latitude. This investigation refers to ordinary days; that is, all days excepting those highly disturbed. The inequality for such days does not follow the same laws at high latitudes as at low latitudes. At high latitudes the current is roughly of equal intensity during the day and during the night, and the twenty-four-hour wave is predominant. At low latitudes the day-current is predominant and the twelve-hour wave is very evident.

A more profound study of the great amount of observations from Sodankylä[2] has given opportunity of prosecuting the solution of these problems by classification of the days of the year September, 1882, to August, 1883. The results are given in Table 1, columns 2 to 7. Columns 2 and 5 show the diurnal inequality on quiet days for the northward and the eastward components respectively. The values in column 2

Table 1

1	2	3	4	5	6	7	8	9	10	11	12	13
	Diurnal inequality of normal earth-current in millivolts per kilometer											
Local time	Sodankylä (67°N)						Lund (56°N)					
	ΔN			ΔE			ΔN			ΔE		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
h												
1	+0.0 (2)	+0.9	+0.4	+0.3	−3.8	−1.3	−0.09	−0.93	−0.18	0.00	+1.14	+0.50
3	−0.0 (1)	+0.7	+0.2	−0.2	−4.1	−2.8	−0.05	−0.75	−0.14	+0.05	+0.91	+0.37
5	+0.0 (4)	0.0	+0.4	−0.4	−3.7	−2.5	−0.19	−0.32	−0.31	+0.35	+0.18	+0.17
7	+0.0 (6)	−0.2	+0.1	+0.1	+1.5	−0.3	−0.73	−0.24	−0.56	+1.32	+0.38	+0.42
9	0.0 (0)	+0.1	−0.1	+0.5	+4.8	+1.2	−0.30	+0.13	+0.04	+0.36	−0.08	+0.44
11	−0.0 (4)	0.0	+0.1	+0.7	+3.8	+2.5	+0.31	+0.35	+0.27	−0.70	−0.37	−0.15
13	+0.0 (2)	−0.6	−0.3	−1.0	+3.7	+1.4	+0.47	+0.50	+0.51	−1.01	−0.73	−0.45
15	−0.0 (1)	−0.9	−0.6	−0.7	+3.0	−0.5	+0.44	+0.75	+0.87	−0.85	−1.15	−0.20
17	−0.0 (1)	−0.2	+0.2	−0.1	−0.3	−0.7	+0.20	+0.80	+0.57	−0.10	−1.19	−0.44
19	0.0 (0)	−0.1	−0.3	0.0	−1.6	+0.5	+0.14	+0.51	+0.07	−0.01	−0.34	−0.57
21	−0.0 (1)	0.0	0.0	+0.4	−1.3	+1.4	+0.09	+0.26	−0.29	+0.11	−0.21	−0.51
23	−0.0 (2)	+0.3	+0.1	+0.5	−2.2	+0.9	−0.24	−1.07	−0.83	+0.38	+1.46	+0.46
Average departure from mean	0.0 (2)	0.3	0.2	0.4	2.8	1.3	0.27	0.55	0.39	0.44	0.68	0.39

[1] Étude des courants telluriques. Deuxième fascicule. Mémoires publiés par la Direction Générale des Télégraphes de Suède, Stockholm, 1930. This paper may be obtained, free of charge, from K. Telegrafstyrelsen, Brunkebergstorg 2, Stockholm, Sweden. Copies of the first fascicle may also be obtained there.

[2] S. Lemström. L' exploration internationale des régions polaires 1882-83 et 1883-84. Expédition polaire finlandaise, Helsingfors, 1886.

THE EFFECT OF THE SUNSPOT-CYCLE ON THE MAGNETIC DIURNAL VARIATION AT APIA

By C. J. Westland

Abstract—In this article the data used are the hourly values in magnetic declination, D, and horizontal intensity, H, each hourly value having been computed from the mean ordinate to the curve during the period of sixty minutes commencing at the Greenwich hour stated. The difference between the highest and lowest hourly value in the day is called simply the "Range," brevitatis causâ. Results of harmonic analyses are given following the notation H or $D = m + r_1 \sin(A_1 + t) + r_2 \sin(A_2 + 2t) + \ldots\ldots$

In preparing to make harmonic analyses of the diurnal variations of the magnetic elements at Apia, the first difficulty was to find the most suitable material. We have mean curves derived from the all-day results in the years 1905 to 1929, and it might seem natural to use these values. But the objection to using any such mean curve is that the effect of the sunspot-cycle upon the ranges in magnetic horizontal intensity, H, is so pronounced, that the values of the coefficients must depend upon the number of years of sunspot maximum included in the period contributing to any such mean curve. Obviously there can not be a normal curve in the real sense of the word.

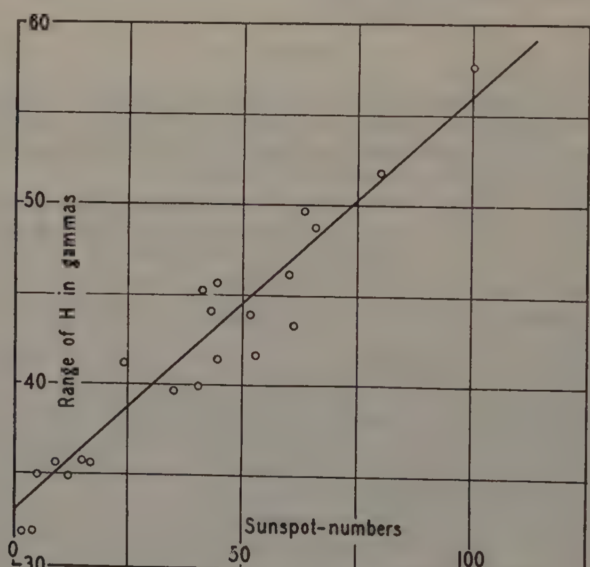


Fig. 1

To show how conspicuous the effect is upon the ranges in H, consider Figure 1. Here the mean ranges expressed in γ during March, April, September, and October in each year from 1905 to 1927 are plotted vertically above the sunspot-numbers taken from left to right. The ranges at the seasons of the solstices give results similar to these shown

at the equinoctial seasons. If we consider Figure 1 to be the graph of $R\gamma = (33 + 0.22S)$, then the result found at the season of the northern solstice, May, June, July, August, is the graph of $(22+0.20S)$, and the remaining four months representing the southern solstice give $(37+0.20S)$.

When the ranges and the sunspot-numbers are treated as problems in correlation, the coefficients are found to be unity or nearly so, showing that this method is not suitable for the purpose for which it has been used.

Under these circumstances it must be seen that the only plan that can give useful results is to compute the harmonic constants at both maximum and minimum periods of solar activity. The means for each month in the years 1917, 1918, and 1919 have been taken for the time of maximum activity, and similar data for 1922, 1923, and 1924 have been used for the time of minimum.

The results in H are shown in Table 1. The coefficients of the first and second terms are respectively 30 and 34 per cent greater at maximum, than those found at minimum.

The problem in magnetic declination, D, is rather more complicated, because there are always two maxima and minima in the diurnal curve. Also there is an annual variation which has the effect that if we were to consider merely the highest and lowest hourly values, we should be contrasting different parts of the curve at different seasons of the year. It is for this reason that I have never tabulated absolute daily maxima and minima in D in the Apia reports—such data would be meaningless and even misleading.

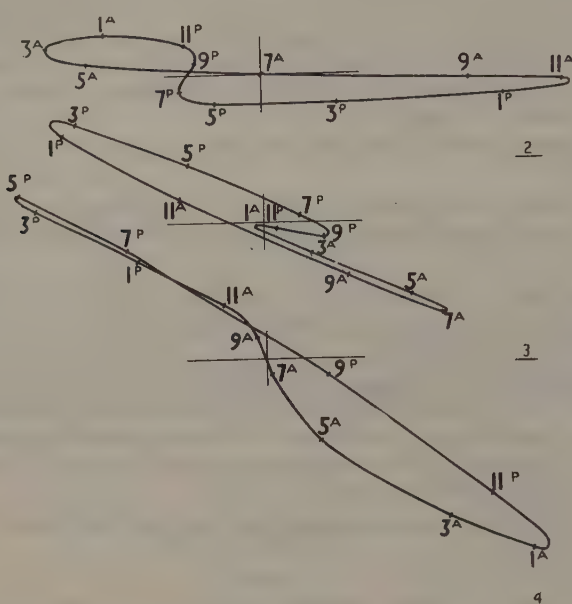
The values in D when examined by graphical methods show no evidence whatever of any sunspot-effect. In order to use them as a problem in correlation, the rule was made that the first maximum in the day and the second minimum were always used for obtaining the range. The coefficients for all three seasons of the year were then

TABLE 1—*Results of harmonic analyses of diurnal variation in magnetic horizontal intensity, Apia, Western Samoa, 1917-19 and 1922-24*

Month	Period maximum solar activity Years 1917, 1918, and 1919								Period minimum solar activity Years 1922, 1923, and 1924							
	r_1	r_2	r_3	r_4	A_1	A_2	A_3	A_4	r_1	r_2	r_3	r_4	A_1	A_2	A_3	A_4
	γ	γ	γ	γ	$\circ$	$\circ$	$\circ$	$\circ$	γ	γ	γ	γ	$\circ$	$\circ$	$\circ$	$\circ$
Jan.	20.8	11.4	3.7	1.2	107	116	134	118	15.8	9.6	2.9	2.1	103	113	157	220
Feb.	17.4	12.5	4.5	0.9	121	119	144	215	13.5	9.5	4.2	1.2	112	114	128	176
Mar	20.7	12.6	4.1	1.3	116	120	142	176	15.3	8.8	3.0	0.3	100	111	113	150
Apr.	18.6	8.6	2.8	1.2	124	127	137	155	12.2	5.9	1.8	1.5	125	127	136	169
May	16.7	6.7	1.2	1.1	137	143	212	49	9.8	1.8	1.3	1.8	134	139	312	299
June	14.2	5.6	1.5	0.6	131	140	203	123	10.4	4.6	1.1	0.1	135	161	201	300
July	16.5	5.4	1.7	0.6	132	141	170	104	10.7	3.4	1.7	0.6	133	137	137	97
Aug.	22.5	7.2	1.7	1.0	125	146	171	94	12.9	5.3	1.5	1.0	123	150	162	73
Sep.	22.6	7.9	2.9	1.7	123	140	199	20	16.6	6.1	1.8	1.7	127	128	166	172
Oct.	22.6	10.9	4.9	0.5	117	120	152	235	12.9	8.2	2.8	0.3	121	122	135	142
Nov	22.4	12.4	5.1	0.7	109	122	148	215	18.8	12.3	4.3	0.9	105	115	137	288
Dec.	22.1	12.2	4.5	0.4	111	121	150	180	17.4	10.6	5.4	0.9	105	122	137	174

Bauer[6] states that the resultant horizontal component of the earth-currents at Ebro is approximately *in the direction from the magnetic north pole* towards south-southeast.

Similar statements have been made regarding the other European stations. At Watheroo[7] the changes take place also approximately along the magnetic meridian.



Figs. 2, 3, 4

Chree[8] already in 1912, in a similar investigation of magnetic elements, says: "When deriving diurnal inequalities of declination for ordinary days at Kew from the records of the eleven years, 1890 to 1900, I omitted the curves of 209 days being highly disturbed. It occurred to me to try whether these 209 days, when treated separately, gave anything resembling a regular diurnal inequality. . . . It was a great surprise when definite inequalities made their appearance not merely from the 209 days combined, but even from the limited number belonging to each of the twelve months of the year." At Kew the difference of type between disturbed-day and quiet-day inequalities is considerably less for horizontal (H) and northward (X) magnetic components than for declination (D) and eastward (Y) magnetic component. At Sodankylä[9] the difference of type is very prominent.

The diagrams in Figure 5 represent the diurnal inequality on quiet and disturbed days at Sodankylä in the year 1921. The quiet-day inequalities are derived from the 60 international quiet-days and the

[6] L. A. Bauer, Terr. Mag., **27**, 5-7 (1922).

[7] O. H. Gish and W. J. Rooney, Terr. Mag., **33**, 79-90 (1928).

[8] C. Chree, Studies in terrestrial magnetism, London, 1912, p. 55.

[9] H. Hyyrylaïnen, Ergebn. Beob. Mag. Obs. Sodankylä, 1921.

disturbed-day inequality for $\triangle X$ is derived from 45 days with range greater than 300γ and that for $\triangle Y$ from 30 days with range greater than 150γ.

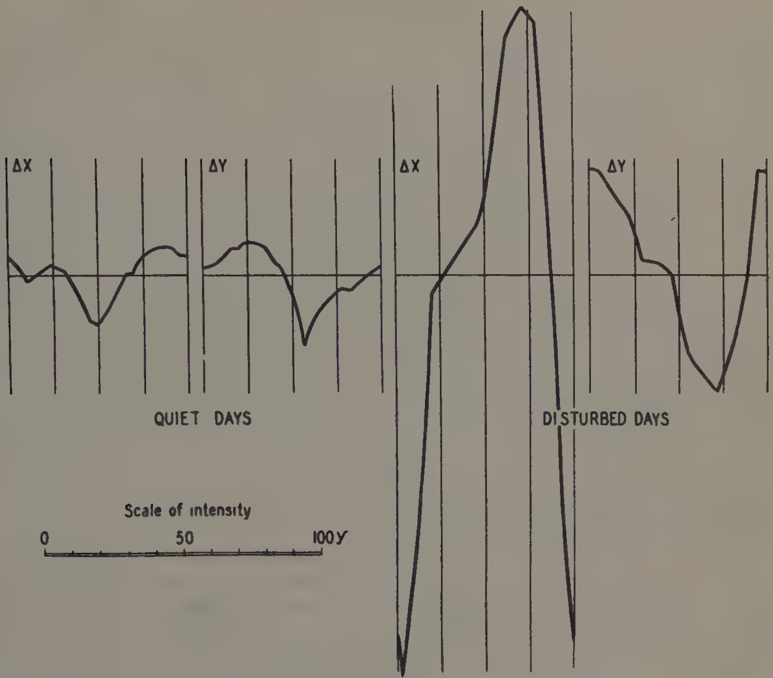


FIG. 5

It is conceivable that diurnal inequalities of the low-latitude type for earth-currents and for the magnetic elements are connected with the ultraviolet radiation of the Sun, that the high-latitude type is connected with ordinary auroral rays having diurnal variation, and finally that the magnetic storms are connected with the cosmic rays, which have diurnal variation.

TELEGRAFVERKETS PROVNINGANSTALT,
Stockholm, Sweden,
March, 1931

REVIEWS AND ABSTRACTS

(See also page 147)

POLLAK, L. W.: *Die Perioden und der Periodogramm der internationalen erdmagnetischen Charakterzahlen.* Prager Geophysikalische Studien III. Prag, Čech. Statistik, Bd. 64, Reihe 12 (Landwirtschaft Heft 13), 1930 (107). 31 cm.

This is one of a series of important publications by Professor Pollak of Prague, and Dr. Stumpff of Breslau, on the subject of periodogram-analysis in general, and, in particular, on the application of tabulating- or punched-card machines to such analysis. The present work was undertaken at the suggestion of Professor Adolf Schmidt of Gotha, who had made extensive investigations on the question of a 30-day period in magnetic disturbances. Professor Pollak did not confine himself to the 30-day period, as first suggested, but made a periodogram-analysis of the 21 years (1906-1926) of international magnetic character-numbers. The number of daily values was thus 7670, and in view of the fact that in the vicinity of two of the suspected periods it was found desirable to try for periods at intervals of 1/10 of a day and even 1/100 of a day, the amount of work would have been prohibitive without the tabulating-machine and the theory of its use in periodogram analysis.

All workers in observations containing hidden periods are under obligations to Professor Pollak and Dr. Stumpff for the development of a practical and reliable method of determining these periods. Those interested in terrestrial magnetism owe a special debt to Professor Pollak for his thorough, complete, and painstaking analysis of the character-numbers. Many investigations had previously been made of these, especially for the 27-day period, by well-known workers in terrestrial magnetism. Professor Pollak's analysis is a complete answer to many of the questions raised in these investigations and a starting point for future work along the same lines. It would be desirable, in a very few years, to extend the work to the further accumulated data, four years of which are already at hand. It seems assured now that no one would have the temerity to undertake such an extension without the aid of the tabulating-machine and the methods used by Professor Pollak.

Evidently this analysis has settled the question of the 30-day period in the character-numbers for the time considered, 1906-1926, 21 years. It turns out that there are two periods of very nearly 30 days' length, namely, one of 29.9 days and another of 30.1 days, with respective amplitudes of 3.87 and 3.20 in units of expectancy or of the mean amplitude. The probability that the first amplitude is of accidental origin is not as great as 1/125,000, while for the second, the probability is not as great as 1/3,000. It should be stated, however, that these probabilities become larger when one uses the less favorable value of the mean ordinate arising from all the trial periods of the analysis. In this case the respective probabilities are not as great as 1/7,490 and 1/450. Even with these increased probabilities one may feel pretty thoroughly convinced that it has been established that periods of 29.9 days and 30.1 days exist in the magnetic character numbers for 1906-1926. It remains to be seen whether this throws any light on the relation of magnetic activity to solar phenomena.

One other period appears to have been established by this investigation, namely one of the surprising length of 9.00 days. The amplitude of this period is 2.72 in units of the mean amplitude of all the trial periods. The corresponding probability that it is accidental is not as great as 1/330.

The following table gives the remaining trial-periods having the least probability of accidental occurrence. The amplitudes are in units of the mean amplitude of all trial-periods. The third line gives the corresponding probability of accidental occurrence.

Length of period in days........	9.02	9.01	16.50	27.00
Amplitude....................	2.46	2.06	1.87	1.77
Probability less than...........	1/115	1/27	1/15	1/11

In two regions the trials were made at intervals between periods small enough to discover all waves that might exist in the observations examined. These are the regions in the vicinity of 9 days and 30 days, and for these intervals the periodogram is final. Since the application of the close-interval procedure, the Darwin process, to these two regions increased the mean amplitude in both cases, it is natural to ask whether a complete periodogram of these observations would have a mean amplitude sensibly larger than the one used in the above table. In case of increased mean amplitude the probabilities of accidental occurrence become greater.

It is to be hoped that Professor Pollak will continue this investigation in which he has already made such noteworthy advances.

C. R. DUVALL

DIURNAL VARIATION OF CONCENTRATION OF CONDENSATION-NUCLEI AND OF CERTAIN ATMOSPHERIC-ELECTRIC ELEMENTS AT WASHINGTON, D. C.

By G. R. Wait

Abstract—Diurnal-variation observations of the concentration of condensation-nuclei in the atmosphere and of certain meteorological elements have been made simultaneously with those of the potential gradient and of the electric conductivity of the atmosphere. The diurnal-variation curve for condensation-nuclei is similar to the general temperature-curve in that high values occur during the daylight hours and low values during the night. The curve is somewhat similar to that for the potential gradient and in a very general way inverse to that for the atmospheric conductivity. The rate of ionization calculated from the linear recombination-law, shows a diurnal-variation curve very similar to that for the negative air-earth current as computed from the potential gradient and the negative conductivity.

The results of this investigation suggest that relative humidity is not a large factor in determining the number of nuclei present in the atmosphere. Calculated values of negative conductivity by means of both the linear recombination-law and the square-root law show fair agreement with the observed values of the conductivity—neither shows any decided advantage over the other.

Several mechanisms whereby the diurnal variation of potential gradient at Washington may be accounted for through the observed number of condensation-nuclei, charged or uncharged, are considered. In view of the known universal character of the diurnal variation of the potential gradient, it was considered necessary to explain only a portion of the diurnal variation through some such mechanism. On the basis of experimental results it is shown that this portion may be entirely accounted for through variation in height and in density of a local space-charge. The necessary variation in height can be satisfactorily explained through the action of local convection-currents in the atmosphere while the required variation in density can be explained through a variation in the number of condensation-nuclei.

Evidence is presented in support of a theory that the secondary minimum in the potential-gradient diurnal-variation curve, occurring at many land stations during the warmest time of the day, is produced through the mechanism of convection-currents in the atmosphere.

The amount of published data on the concentration of condensation-nuclei, and especially of those taken simultaneously with observations on any of the atmospheric-electric elements, is small. The need for additional data is only too apparent to the workers in atmospheric electricity. The presence of condensation-nuclei is one of the several factors affecting the number of small ions in equilibrium in the atmosphere, and considerable data will be required to experimentally determine precisely how it operates. Some of the doubtful points in this connection could perhaps be better studied in the laboratory, yet there is need to secure data for out-door conditions. With this in mind, data have been accumulated at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington on the diurnal variation of the concentration of condensation-nuclei. All of the diurnal-variation series were made in the month of March—two during 1927 and one each in 1928 and 1930. Observations simultaneous with the nuclei-count were made on the force and direction of the wind, type and amount of cloud, barometric pressure and air-temperature, and during the last two series determinations of the relative humidity. Records from instruments continuously recording the electrical conductivity and potential gradient of the atmosphere, operating in an observatory (hereafter referred to as the Deck-Observatory) on the roof of the Department's Laboratory have provided data for studying the relation of these elements to the nuclei.

It has been noted on frequent occasions by other observers that the nearness of the observing station to a source of pollution of the atmos-

phere and the direction and force of wind with respect to source of pollution and observing station, have been some of the factors in determining the number of nuclei present. The Laboratory of the Department is on a prominent hill about nine kilometers to the northwest of the main business and residential section of the City. A wooded area almost free from houses lies between the business section of the City and the Laboratory. Only to the west and northwest does the residential district approach within a few hundred meters of the Laboratory, consequently air bearing pollution from domestic fires, except for those quarters, must pass over several miles of wooded area before reaching the Laboratory. Very few large factories, such as are found in other cities of similar size, are located in Washington; consequently the pollution from such sources is much limited at the Laboratory site.

The concentration of condensation-nuclei was determined with an Aitken pocket dust-counter, the counts being made about one meter above the surface of the ground, some 25 meters east of the Laboratory building. Each determination was the mean of ten separate counts, and each count consisted of the sum of the particles falling in all the separate expansions in that count. In general each determination lasted about ten minutes and was centered on the hour, the interval between determinations being one hour. With the exception of the observations made March 21, 1927, each series began at 14 hours, seventy-fifth meridian time. Fair weather prevailed during all the series except the first, when either rain or fine mist occurred during the majority of the determinations. On March 21 the instrument was protected from rain by an umbrella, which was left up during the whole period of observation, even when no rain was falling. On the other occasions the instrument was unprotected.

The collector of the potential-gradient apparatus on the roof of the Laboratory is about 15 meters above the general ground-level. A quadrant-electrometer is used as recording instrument in the potential-gradient apparatus. The needle of the electrometer is connected to an active ionium-collector and good insulation is maintained throughout the system. The apparatus is calibrated each day, thus making it possible to secure reliable scale-values for converting the recorded electrometer-deflections into volts. Observations for the purpose of securing a reduction-factor for converting the observed volts to volts per meter, are made several times each year.

The intake of the air-flow tube of the conductivity-apparatus is about one meter higher than the potential-gradient collector. The apparatus is not of the duplex type, which permits of the recording of both signs simultaneously (such as those in use at the Watheroo, Huancayo, and the Tucson observatories) and only one sign at a time is obtained here. The apparatus is of the continuous deflection type, and has been briefly described by Swann.[1]

Although the potential gradient and the conductivity were recorded on all of the occasions when the nuclei-counts were made, the irregular character of these elements on March 21, due to meteorological disturbances, was such that the data for that day were not used in the present analysis. The data on nuclei-counts are, however, utilized, since they appear to be little affected by the meteorological conditions.

[1]Carnegie Inst. Year Book, No. 16, 279-281 (1917).

The hourly values of the potential gradient and of the conductivity used in the analysis are centered on the half-hour, having been obtained by scaling the mean ordinate between hour-marks on the record.

OBSERVATIONAL RESULTS

Table 1 gives the individual hourly values, on seventy-fif h meridian mean time, of the concentration of condensation-nuclei for each of the 24-hour series and their means. Table 2 gives minimum, maximum, and average values of the concentration of condensation-nuclei and of atmospheric-electric values.

TABLE 1—*Condensation-nuclei (N_A), in thousands per cc, as measured with an Aitken nuclei-counter at Washington, D. C.*

75° M. T.	March 21, 1927	March 23-24 1927*	March 27-28 1928*	March 27-28 1930*	Mean of the 4 days
h					
0	7.1	11.5	30.4	13.2	15.6
1	4.7	10.9	28.1	8.8	13.1
2	4.7	14.1	25.7	9.8	13.6
3	5.4	11.4	22.0	13.4	13.0
4	4.9	13.1	18.5	10.8	11.8
5	5.6	11.9	12.2	12.1	10.4
6	5.4	9.3	14.6	14.6	11.0
7	7.5	11.3	14.2	32.1	16.3
8	10.2	23.6	14.6	25.4	18.4
9	17.8	17.1	27.1	37.2	24.8
10	35.4	19.8	38.1	39.7	33.2
11	24.8	27.0	45.0	36.3	33.3
12	24.3	24.3	26.9	37.8	28.4
13	22.8	15.6	33.3	29.2	25.2
14	11.9	15.6	54.7	27.5	27.4
15	14.9	21.1	48.2	31.5	28.9
16	21.8	29.3	42.2	22.0	28.8
17	15.6	18.8	36.9	24.6	24.0
18	35.5	26.0	28.7	36.3	31.6
19	29.5	28.8	46.2	21.6	31.5
20	18.4	22.3	29.2	27.5	24.4
21	28.8	18.1	21.7	21.6	22.6
22	23.1	19.3	26.6	16.6	21.4
23	37.5	13.7	40.4	15.1	26.7
Mean	17.4	18.1	30.2	23.5	22.3

*Each series was begun at 14^h in the earlier date indicated.

TABLE 2—*Daily mean values*

Date	Number of condensation-nuclei per cc			Potential gradient volts per meter			Negative conductivity in ESU × 10—5		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
March 21, 1927....	4,700	37,500	17,400	...	...	...	....	....	....
March 23-24. 1927..	9,300	29,300	18,100	112	224	153	1.09	3.30	1.84
March 27-28, 1928..	12,200	54,700	30,200	66	176	108	0.93	2.84	1.87
March 27-28. 1930.	8,800	39,700	23,500	26	172	110	0.54	1.98	1.16

Graphs of the diurnal variations and their means, in concentration of condensation-nuclei and in air-temperatures, are given for the four series in Figure 1. In Figure 1 are also given the relative humidity graphs obtained (*a*) at the central station of the United States Weather Bureau, distant about 6.5 km, and (*c*, *d*) at the nuclei-station; the latter were in such good agreement with simultaneous records from the Weather Bureau station as to justify considering the former as also representative of humidity-conditions at the nuclei-station on March 21, 1927. Special interest is attached to the humidity-conditions on that date, as will appear later.

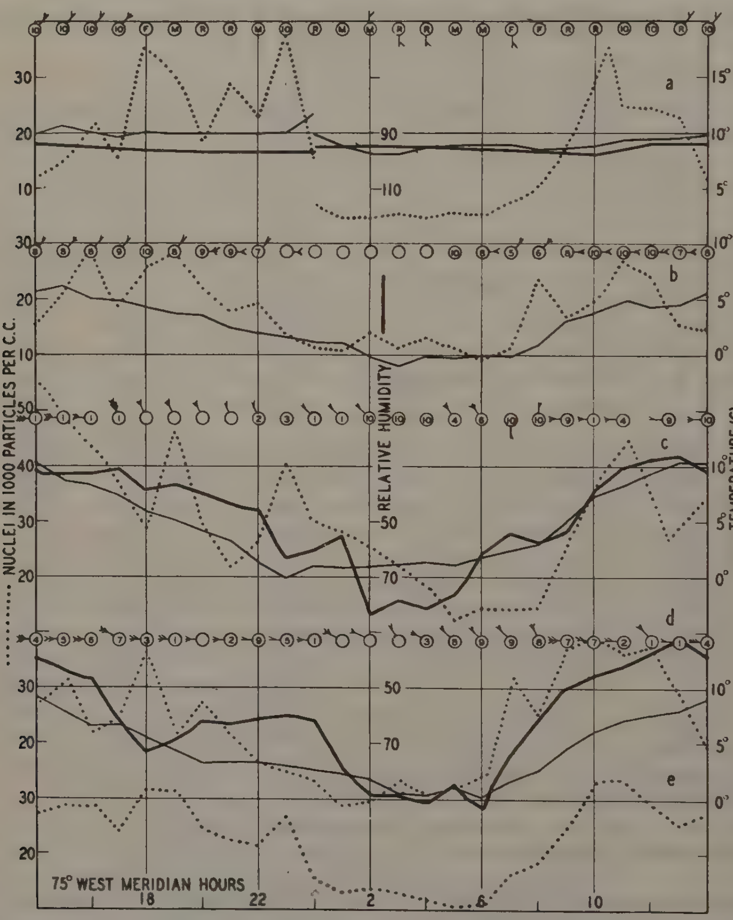


FIG. 1—Diurnal variation at Washington, D. C., in concentration of condensation-nuclei, in relative humidity, and in temperature—(*a*) March 21, 1927, (*b*) March 23-24, 1927, (*c*) March 27-28, 1928, (*d*) March 27-28, 1930, and (*e*) their means (amount of cloud on scale of ten is indicated by number given in circles and the arrows on circles fly with wind, north being at top of page and number of feathers indicating force on Beaufort scale; the letters *R*, *M*, and *F* in circles indicate rain, mist, and fog, respectively)

Figure 1 also gives the condition of the weather at the time of each nuclei-count, including the amount of cloud and the force and direction of the wind; the letters *R*, *M*, and *F* inside the circles indicate rain, mist, and fog, respectively. The amount of cloud on a scale of 10 is shown by a number inside the circles, and the direction of the wind is indicated by the direction the arrow is flying, north being toward the top of the Figure. The force of the wind on the Beaufort scale is shown by the number of feathers on the arrow, the absence of an arrow indicating calm and the absence of a number ndicating clear sky.

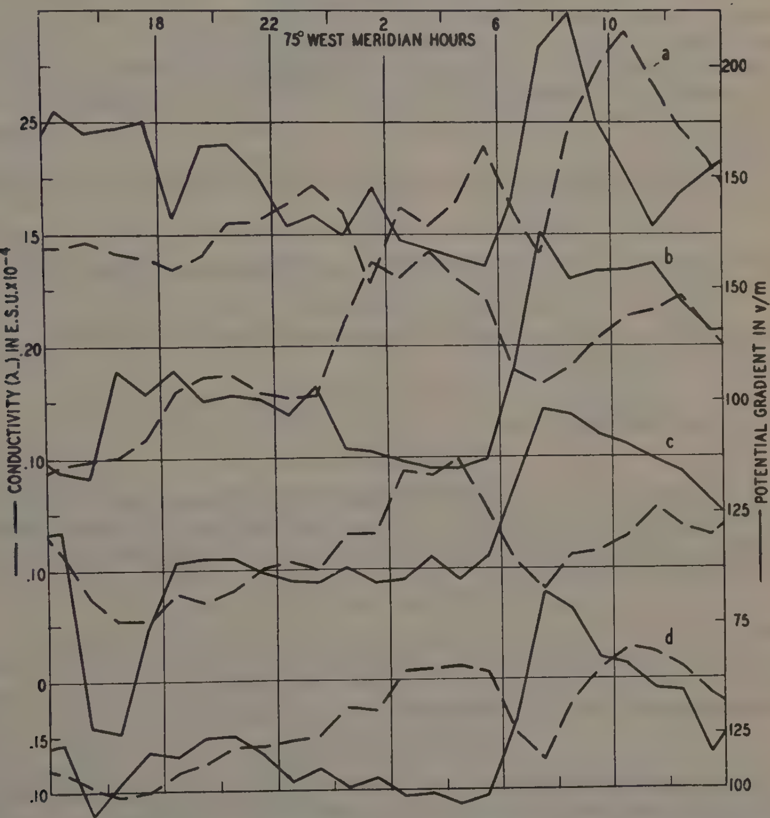


FIG. 2—Diurnal variation at Washington, D. C., in observed negative conductivity and potential gradient of the atmosphere—(*a*) March 23-24, 1927, (*b*) March 27-28, 1928, (*c*) March 27-28, 1930, and (*d*) their means

In Figure 2 are given diurnal-variation graphs and means for atmospheric conductivity and potential-gradient obtained from records made in the Deck-Observatory during the last three of the series of nuclei-observations. Observed data only were used in drawing Figures 1 and 2. Many of the graphs in Figures 3 to 7 are from computed quantities; the significance of these will be indicated later in the discussion of observed and computed results.

Using the nuclei-data in Figure 1 and the conductivity-values from

Figure 2, the rate at which small ions are generated in the atmosphere was computed from Schweidler's equation.[2] Although some investigators in the field of atmospheric electricity doubt that this equation is capable of representing the conditions of ionization with very great precision, no other equation has yet been proposed. While modifications of the present equation have been proposed, they do not alter the essential character of any diurnal-variation curve for ionization computed from the original formula. In discussing the application of the Schweidler equation to the present analysis, the following terms will be used: n_+ = small positive ions; n_- = small negative ions; N_+ = positively-charged nuclei (large ions) per cc; N_- = negatively charged nuclei (large ions) per cc; N_0 = uncharged nuclei per cc; N_A = total condensation-nuclei per cc; α = coefficient of recombination between small ions; η_2 = coefficient of recombination between ions and oppositely charged nuclei; η_1 = coefficient of recombination between ions and uncharged nuclei.

Schweidler[2] developed an equation of ionic equilibrium of the following type

$$q = \alpha n_+ n_- + \eta_2 n_\pm N_\mp + \eta_1 n_\pm N_0 \tag{1}$$

By assuming that the space charge was zero he also showed that

$$n_+ = n_- \text{ and } N_+ = N_- \tag{2}$$

Nolan, Boylan and De Sachy[3] later showed that for equilibrium-conditions for the large ions

$$\eta_2 N_\pm = \eta_1 N_0 \tag{3}$$

These relationships give for (1)

$$q = \alpha n^2 + 2\eta_2 N_\pm n \tag{4}$$

On the assumption that condensation-nuclei are composed of large ions and uncharged nuclei, which is supported also by some experimental evidence,[3] and using the relationship between the number of large ions as given in (2),

$$N_0 + 2N_\pm = N_A \tag{5}$$

Substituting for N_0 its equivalent $(\eta_2/\eta_1)N_\pm$ in (5) and using (4),

$$q = \alpha n^2 + [2\eta_1\eta_2/(2\eta_1 + \eta_2)] \tag{6}$$

Substituting $N_0/N_\pm = \eta_2/\eta_1 = R$ and $\omega = \eta_2\,[2/(R+2)]$

$$q = \alpha n^2 + \omega N_A n \tag{7}$$

The values of η_2 and R have been determined experimentally by several different investigators with considerable consistency. The most recent determination[4] of R gave a value of 2.2 in good agreement with some of the previous ones. Among the recent determinations of η_2 are: 5.6×10^{-6} from Schlenck's[5] 1924 data by assuming the sum of the mobilities of the small ions equal to 2 cm sec/volt/cm; 6.4×10^{-6} by P. J. Nolan and C. O'Brolchain in 1929,[6] assuming the sum of the mobilities of the small ions is 2.9 cm/sec/volt/cm; and 6.8×10^{-6} by Hess in 1929.[7] If 6.3×10^{-6} be taken as the value for η_2 and 2.2 as the value for R, ω becomes 3.0×10^{-6}.

[2]Wien., Ber., **127**, 953-961 (1918); **128**, 947-953 (1919); **133**, 23-27 (1924).
[3]J. J. Nolan, R. K. Boylan, and G. P. de Sachy, Proc. R. Irish Acad., A, **37**, 1-12 (1925).
[4]J. J. Nolan and P. J. Nolan, Beitr. Geophysik, **25**, 414-428 (1930).
[5]Wien. Ber., **133**, 29-33 (1924).
[6]Proc. R. Irish Acad., A, **38**, 40-48 (1929).
[7]Beitr. Geophysik, **22**, 256-314 (1929).

This value of ω was used in (7), together with values of n computed from the observed values of conductivity (assuming that the mobility of the negative ion was 1.5 cm/sec/volt/cm) and with observed values of N_A (interpolation being made between the observed values on the hours to center the values on the half-hour to agree with the conductivity-scalings), to compute hourly values of q for March 23-24, 1927, March 27-28, 1928, and March 27-28, 1930. The resulting diurnal-variation graphs and mean for q are shown in Figure 3. In the above

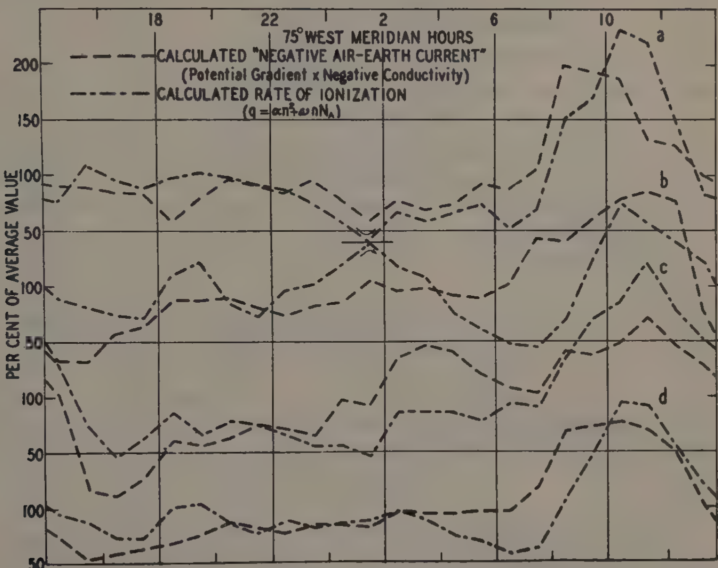


FIG. 3—Calculated "negative air-earth current" and calculated rate of ionization at Washington, D. C.—(a) March 23-24, 1927, (b) March 27-28, 1928, (c) March 27-28, 1930, and (d) their means

calculations the term αn^2 was neglected, being negligibly small in comparison with $\omega n N_A$. Figure 3 also gives plots of negative air-earth current, each hourly value being the product of observed values of negative conductivity and potential gradient.

The diurnal-variation graphs for q show approximately a constant value for this element during all hours of the day except those between 8^h and 16^h, when the variation was considerable. Assuming a constant value for q equal in each case to be the mean of the 18 hourly values (excluding those for 8^h to 14^h), and further that the conductivity of the air was inversely proportional to its nuclei-content, values of n were computed from (7). From these values of n, assuming the mobility constant equal to 1.5 cm/sec/volt/cm, hourly values of the conductivity were computed. The resulting individual mean conductivity-graphs are shown in Figure 4.

P. J. Nolan[8] observed that the value of ω did not remain constant, but varied in such a manner that the value of $\omega\sqrt{N_A}$ tended to be constant. Hess,[7] although observing a variation in ω, could not con-

[8]Proc. R. Irish Acad., A, 38, 49-59 (1929).

firm the results of Nolan. It was, therefore, considered of interest to compute the hourly values of the conductivity on the basis of Nolan's equation, that is, on the basis of the conductivity being inversely proportional to the square root of the number of nuclei per cc. The diurnal variation of the conductivity-values and means thus computed are included in Figure 4, which also shows the observed values to facilitate comparisons.

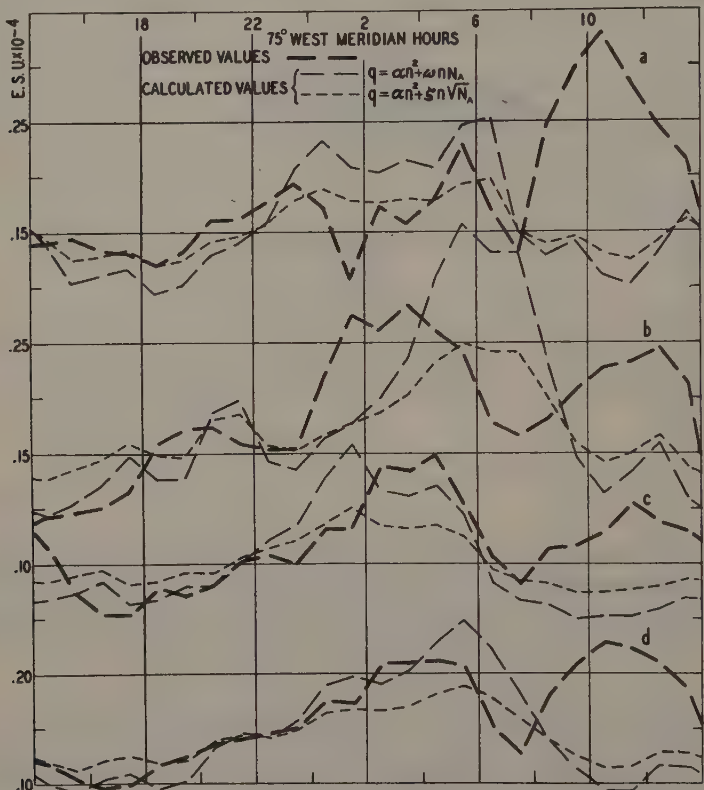


FIG. 4—Diurnal variation at Washington, D. C., of negative conductivity as observed and as calculated on basis of two equations—(*a*) March 23-24, 1927, (*b*) March 27-28, 1928, (*c*) March 27-28, 1930, and (*d*) their means

Graph *a* of Figure 5 shows the diurnal variation of concentration of condensation-nuclei on March 21, 1927; the percentage of average value was obtained from the ratio of each hourly value in the series to the mean hourly value of the series. The other graphs of Figure 5 show for the remaining three series observed, the diurnal variations for the concentration of condensation-nuclei, for potential gradient, and for the negative air-earth current and their means.

Gish and Sherman[9] developed an apparatus for obtaining continuous records of the electric charge of the air and operated it at the Department of Terrestrial Magnetism in Washington, D. C., during October

[9]Carnegie Inst. Year Book No. 28, 261 (1929).

and November, 1928. The design is a modification of Obolensky's method for obtaining the space-charge of the atmosphere. The diurnal-variation graph shown in Figure 6 of the electric charge of the atmosphere in e.s.u. per cubic meter is that resulting from their records obtained during eleven days in November, 1928. Figure 6 shows also the mean diurnal-variation graphs of condensation-nuclei per cc of air for March 21 and 23-24, 1927, March 27-28, 1928, and March 27-28, 1930.

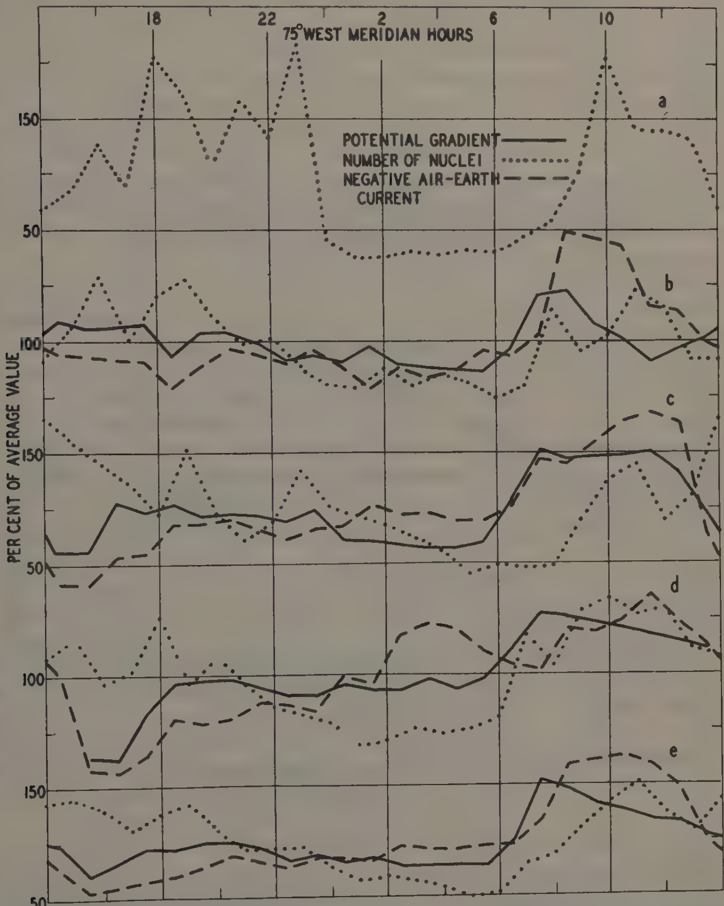


FIG. 5—Diurnal variation at Washington, D. C., of potential gradient, number of condensation-nuclei, and negative air-earth current—(*a*) March 21, 1927, (*b*) March 23-24, 1927, (*c*) March 27-28, 1928, (*d*) March 27-28, 1930, and (*e*) mean of the three days in March 1927, 1928, and 1930

During November, 1928, there were twelve complete days of successful registration of potential gradient aboard the *Carnegie*, which at the time was en route to Easter Island from Panama. During the same period complete potential-gradient records were obtained in the Deck-Observatory of the Department at Washington, D. C., on nine days. Mean hourly values for the month, expressed as percentage of

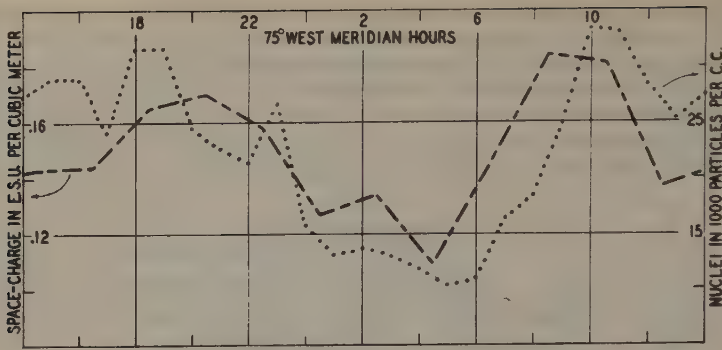


Fig. 6—Diurnal variation at Washington, D. C., of electric space-charge of the atmosphere for mean of eleven days during November 1928 and of number of condensation-nuclei in the atmosphere for mean of March 21, 23-24, 1927, March 27-28, 1928, and March 27-28, 1930

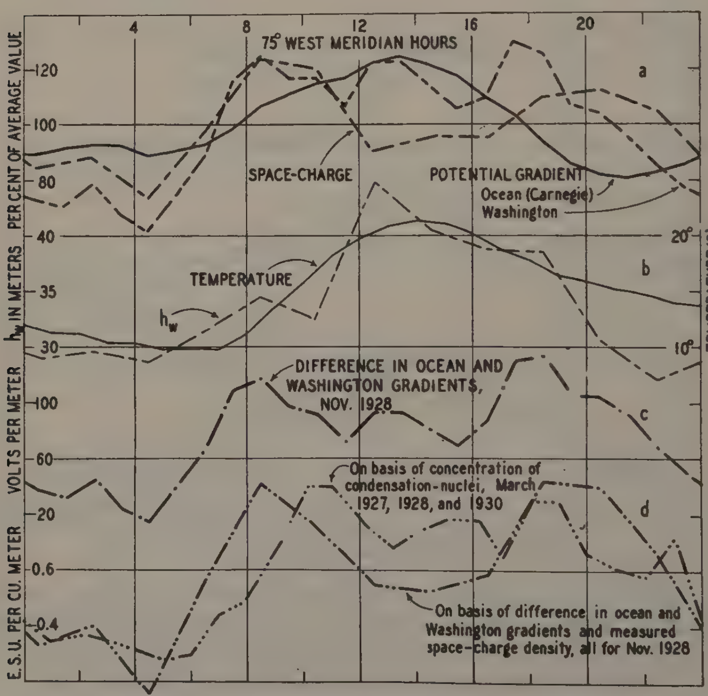


Fig. 7—Diurnal variation (*a*) during November 1928 of potential-gradient mean of 12 days on the *Carnegie*, mean of 9 days at Washington, and of space-charge mean of 11 days at Washington, D. C., (*b*) observed temperatures from thermograms and effective height of space-charge at Washington during November 1928, (*c*) difference between potential gradient at Washington, D. C., and at sea on *Carnegie* during November 1928, and (*d*) two curves of local space-charge density at Washington, D. C., calculated as indicated

average value, for these and the eleven complete records of space-charge density above noted, are plotted in Figure 7*a*. Figure 7*b* also shows averages for thermogram-scalings secured at the space-charge observatory during November, 1928; control-observations on air-temperature made from time to time indicated that corrected temperatures would be only slightly different from those plotted. In this Figure is also plotted the effective height in meters of the space-charge at Washington during November, 1928. The effective height is considered to be the height above the Earth's surface at which the potential gradient would be zero if there were a space-charge of uniform density extending up to that point. The effective height in centimeters was computed by dividing the potential gradient in e.s.u. per centimeter by 4π times the density of the space-charge in e.s.u. per cc.

Figure 7*c* gives the graph of the difference between each corresponding simultaneous hourly value of the gradients recorded on the *Carnegie* at sea and that recorded at the Deck-Observatory in Washington, D. C., during November, 1928, both records being on the same time-scale.

Figure 7*d* shows the density of local space-charge computed on the basis of the number of nuclei per cc. Nolan, Boylan, and De Sachy[3] concluded from experiment that a constant proportion of the condensation-nuclei was charged. J. J. Nolan and P. J. Nolan[4] later found that the ratio of charged to uncharged nuclei underwent considerable variation, yet in the main tended to remain constant. While the assumption that this ratio is constant may be open to question, yet for the purpose in hand it was considered sufficiently valid. By assuming that a slightly smaller proportion of the nuclei was charged negatively than positively, and that the difference between the two sets of charges amounted to 0.061 e.s.u. per cubic meter, the space-charge as plotted was calculated from the nuclei-data.

The other curve in Figure 7*d* for the density of local space-charge was computed on the assumption that a local space-charge at Washington was responsible for the difference between gradients at Washington and at sea during November, 1928, and that the effective height of this local space-charge varied in a manner given in Figure 7*b*. The density in e.s.u per cc was obtained by dividing the difference in gradients in e.s.u. per cm by 4π times the effective height in cm. The resulting computed diurnal-variation graph for space-charge density is expressed, however, in e.s.u. per cubic meter.

DISCUSSION OF OBSERVED AND COMPUTED RESULTS

Examination of the data fails to reveal any correlation between most of the meteorological elements and the condensation-nuclei-content of the atmosphere. Such meteorological elements as the force and direction of the wind, amount and kind of clouds, absolute value of, or change in the barometric pressure, all fail to show any consistent effect upon the density of the nuclei at the observing station. During observations obtained on occasions not included in these analyses, south wind has been observed to be very rich in nuclei; however, in the data here presented a south wind was noted only on a few occasions, and they showed no abnormal number of nuclei. The data of March 21, 1927, give some indications that the concentration of condensation-nuclei is greater during a rain and lower during a mist. Considerably more data would be necessary, however, to substantiate these indications.

The general similarity between the diurnal variation in temperature and in concentration of condensation-nuclei seen in the graphs b, c, and d of Figure 1 is of interest, and raises the question as to a possible explanation. In view of the suspected hygroscopic character of the condensation-nuclei, one might seek an explanation through the relative humidity rather than on the basis of temperature. The rate at which hygroscopic particles disappear from the atmosphere will increase with decrease in the relative humidity. This characteristic will tend to produce a diurnal variation in the concentration of condensation-nuclei similar in character to the reciprocal of the relative humidity. Reference again to graphs c and d of Figure 1, where the relative humidity is plotted with values increasing towards the bottom of the graph, shows that the diurnal variation of the concentration of condensation-nuclei and of the reciprocal of the relative humidity display considerable similarity. This similarity does not appear, however, in the graph a of Figure 1 for March 21, 1927. On that date the temperature at the nuclei-station underwent only a slight variation. The relative humidity curve for the United States Weather Bureau Station also showed but little variation and, making reasonable allowances for possible station-differences, it is not at all likely that the relative humidity varied more than a few per cent at the nuclei-station. The concentration of condensation-nuclei, however, underwent a considerable variation—actually a total percentage-variation greater than on any of the other days. These results, therefore, suggest that the diurnal variation in concentration of condensation-nuclei is due largely to factors other than the variation in relative humidity.

Attention will now be turned to examining the relation between nuclei and the atmospheric-electric elements. The rate at which small ions are formed, the so-called q, is one of the factors in the electrical condition of the atmosphere which it has been possible to examine. As previously stated, values of q were computed with the linear recombination-law, using observed values of conductivity and of condensation-nuclei for the three series of observations. The diurnal-variation graphs resulting from the computed values of q presented in Figure 3 are noteworthy in that for widely separated days they should display such remarkable similarity. The diurnal variation may be described as having a rather sharp maximum which begins at 8^h and ends at 16^h, reaching its highest value at 11^h. For the remainder of the day the curve is comparatively flat, the fluctuations being few and of small amplitude.

P. J. Nolan and Cilian O'Brolchain[10] found that q, when calculated from the linear law, increased with increasing number of nuclei. Two possible explanations were offered by them, one being that radioactive matter may become attached to the nuclei, and the other that the recombination-coefficient between small ions and nuclei varies inversely as the square root of the concentration of the nuclei. Comparison of the curves for q in Figure 3 with the graphs b, c, and d for nuclei in Figure 1, shows for these data little or no resemblance and no systematic differences; thus the present results fail to support those of Nolan and O'Brolchain.

It would be illuminating to find an explanation for the cause of the diurnal variation indicated in the computed values of q. Perhaps they

[10] Proc. R. Irish Acad., A, **38**, 1-17 (1928).

do not really represent the rate of ionization because some of the assumptions involved are false. These assumptions are: (1) That the small ions disappear solely through recombination with small ions and large ions of opposite sign or with uncharged nuclei; (2) that condensation-nuclei are composed entirely of large ions and uncharged nuclei; (3) that the space-charge is zero; (4) that, for equilibrium-conditions, the product of the number of large ions and the recombination-coefficient between them and the small ions is equal to the product of the number of uncharged nuclei and the recombination-coefficient between them and the small ions, which implies that the ratio of charged to uncharged nuclei is constant; and (5) that the mobility of the small ions is constant—a factor involved in computing the number of small ions from values of conductivity. Information is meager regarding each of these; in only a few cases is it possible to determine to what extent the results are affected by not having the assumptions exactly fulfilled.

In any case, it is difficult to understand how the particular shape obtained for the diurnal-variation graph can be explained if the assumptions are false. On the other hand, it is equally difficult to explain the variation if the assumptions are true. Penetrating-radiation is apparently ruled out as being of insufficient magnitude. It is also impossible to correlate the variations with such meteorological factors as a change in barometric pressure or change in direction or velocity of wind, as one should expect to be able to do if the ionization were due to radioactive matter suspended in the air.

Graphs for diurnal variation in the calculated negative air-earth current and for q in Figure 3 show striking similarity. If those for q are accepted as really representing the variations in the rate of ionization, the similarity suggests that the variation in the rate of ionization is entirely responsible for the variation in the negative air-earth current. Two assumptions are involved in such a condition: (1) That when the ionization undergoes an increase, this increase extends to such heights above the surface of the Earth that the total resistance through which the air-earth current passes is proportionately increased; (2) that this ionization-variation is confined to so small an area of the Earth's surface that the total charge of the Earth is not greatly affected. The second assumption requires that the variation in air-earth current shall be a "local-time" effect, but there is reason for believing that the whole diurnal variation cannot be of that type. The diurnal variation of the potential gradient at most stations on land and at sea has been found,[11] in general, to be composed principally of a wave which progresses according to universal time. The conductivity has not been found to vary in a reciprocal manner; therefore the diurnal variation in the air-earth current-density may be regarded likewise as having a wave which progresses according to universal time. The maximum in the air-earth current occurs at about the proper time of day to be the universal effect; thus the agreement between the ionization and air-earth current graphs may be accidental and not related as cause and effect. The agreement, then, cannot be considered as good evidence that the diurnal variation in the computed q actually represents the diurnal variation in the rate of ionization.

Assuming the rate of ionization constant throughout the day, hourly

[11]S. J. Mauchly, Terr. Mag., **28**, 61-81 (1923).

values of conductivity were computed, according to the linear recombination-law and also according to the square-root equation, and the resulting graphs are shown by Figure 4. For q the mean of the computed values previously discussed was used. Comparison of the two computed graphs shows both to be in about equally good agreement with that of the observed data. A disparity between the computed and the observed curves is, however, occasioned by not permitting a variation in the rate of ionization in the computed data.

In the preceding discussions evidence for and against the existence of a diurnal variation in the rate of ionization has been considered. In no case has strong evidence been obtained in support of either side of the question. However, until the present linear recombination-law can be discarded for something better, the computations using that law, showing a very reasonable and possible variation in the rate of ionization, may be accepted.

Having accepted the diurnal variation in the rate of ionization as a factor in the electrical condition in the air, it is of interest to consider the manner in which that variation, together with the variation in number of condensation-nuclei, accounts for the variation in conductivity, assuming constant mobility for the small ions. The curves entering into the discussion are included in Figures *3d* and *4d*. The graph of conductivity (Fig. *4d*) shows a diurnal-variation generally characteristic for the particular time of year at Washington—a rather broad maximum centering roughly at 3^h or 4^h, followed by a narrow minimum at about 7^h, another maximum at about 11^h, with the conductivity increasing with time after 14^h, except for a weak minimum about 17^h towards the early-morning maximum. With the rate of ionization more or less constant from 14^h to about 8^h, the increase in conductivity during this interval appears to be due to the gradual decrease in the nuclei-content of the air. The early morning maximum in conductivity is accordingly brought about largely by a decrease in the number of nuclei in the air, while the narrow minimum immediately following arises through an increase in the number of nuclei. The continued large number of nuclei in the air following the time of this minimum would normally produce low values of the conductivity but for an increased rate of ionization which sets in about this time. The conductivity, therefore, goes through a maximum despite the large number of nuclei present, but falls again to lower values with a decrease in the rate of ionization and eventually passes through the weak minimum at about 17^h—brought about through the combination of an especially low rate of ionization and a large number of nuclei. On this basis the main features of the diurnal variation of the conductivity may be explained as being due entirely to variation in the more elementary factors, namely, ionization of the atmosphere and the concentration of condensation-nuclei.

An abnormally low conductivity is being recorded in the Deck Observatory at the Department (see Fig. 2), being only about one-tenth that found in many other places and about one-third that at ground-level near the Observatory. Measurements of the condensation-nuclei made both on the deck-roof and on the ground near the Observatory have never shown an appreciably greater number at the roof-level. Thus it seems the especially low conductivity found at the Observatory must be explained largely on the assumption that the rate of ionization

there is lower than at the ground. Computation of the rate of ionization q from the linear recombination-law, using as has been done in all this work nuclei-data obtained at the ground-level, together with values of the conductivity from the Observatory, gives the low average of about 5 for q.

Because of the abnormally low conductivity-values being recorded, an atmospheric-electric survey was made in Washington and vicinity[12]. The results showed the conductivity increased with increasing distance from Washington, the largest values (such as those found at the stations more remote from the City) being about three times those found at ground-level near the Observatory-site, while the number of nuclei, on the other hand, decreased with increasing distance from Washington. Thus the low values of conductivity found in the City may be due principally to the large number of nuclei present. On the basis of the linear recombination-law, the effect of condensation-nuclei upon the conductivity may be illustrated by a simple computation, using the average conductivity-value and nuclei-count for the three days considered, namely, about 0.12×10^{-4} e.s.u. and 24,000 particles per cc, respectively. The resulting computed value for q is about 5. If at some given time when the rate of ionization is 5, the conductivity is 0.12×10^{-4} e.s.u., and the nuclei-content of the air is 24,000 per cc, the nuclei-content should in some manner decrease to 2,000 per cc, the conductivity would increase as a consequence, when equilibirum was established, to 1.2×10^{-4} e.s.u.—a value that could be regarded as approximately normal for most land-stations. Two thousand nuclei per cc and $q = 5$, would perhaps be considered low values for these elements for most land stations; they could both be increased 2 or 3 times, making them more nearly normal, and yet leave the computed conductivity at the normal value of 1.2×10^{-4} e.s.u.

Correlation between variations in the number of nuclei and variations in the potential gradient of the atmosphere have been found; some investigators have dealt with the general pollution of the air and not specifically with the condensation-nuclei, and others have discussed changes in visibility caused by atmospheric pollution in relation to the variations in the potential gradient of the atmosphere. Chree,[13] in 1918, using records made at the Kew Observatory, showed a close connection between the limit of visibility of distant objects and the potential gradient. He found that low and high values of the potential gradient accompanied good and poor visibility, respectively. In 1923, Chree and Watson[14] showed a correlation at Kew between the potential gradient and atmospheric pollution as recorded by an Owens air-filter and that, in general, the potential gradient varied in a similar manner as the pollution. Whipple,[15] using additional records from Kew, demonstrated, besides a close parallelism between the daily variation of the potential gradient and of atmospheric pollution as recorded with an Owens air-filter, the introduction of "summer time" in England was accompanied by a shift of the forenoon maximum of the potential gradient to earlier hours—apparently due to the introduction, earlier in the morning, of pollution into the atmosphere.

[12] H. F. Johnston and G. R. Wait, Terr. Mag., 36, 33-40 (1931).
[13] Proc. R. Soc., A, 95, 210-234 (1919).
[14] Proc. R. Soc., A, 105, 311-333 (1924).
[15] Q. J. R. Met. Soc., 55, 1-17 (1929).

From data in 1924 at the Watheroo Observatory, Western Australia,[16] it appears that an increase in the number of condensation-nuclei in the atmosphere is accompanied by a corresponding increase in the value of the potential gradient. Additional data collected there later by Builder[17] are in general agreement with the earlier observations. Further support is given to the earlier results by the data presented in this paper. The individual and mean daily potential-gradient graphs of Figure 5 in general parallel those for nuclei-content. It seems reasonable, therefore, to seek an explanation for the diurnal variation in the potential gradient through the variation in the number of nuclei. That the presence of pollution in the atmosphere considerably affects the value of the potential gradient cannot be doubted, but whether or not it can account for the observed diurnal variation in the gradient requires further consideration.

For fair-weather conditions, it is generally accepted that the potential gradient, conductivity, and air-earth current are so related as to make the product of the first two equal to the last. This relationship has been considered to hold in the following discussions, and the various mechanisms, whereby the condensation-nuclei may affect the potential gradient, will necessarily involve effects upon either the conductivity or the air-earth current or upon both. It will be of interest to consider how far observational results on potential gradient and conductivity and resulting computed air-earth current support various possible mechanisms or processes of action. Five such mechanisms have been considered as possible explanations for the entire diurnal variation in potential gradient at Washington: that is, on the basis of it being purely a local-time phenomenon. Only the fifth fits the observed variations in nuclei, conductivity, negative air-earth current, and potential gradient, but accounts for only a part of the diurnal variation in potential gradient. A final mechanism considered accounts for a part of the entire diurnal variation of potential gradient as a local effect, and the remainder as due to a universal phenomenon. Introducing additional data on the variation in space-charge and potential gradient as recorded at Washington for November, 1928, and the potential gradient over the ocean for the same period, this mechanism makes it possible to fully account for such diurnal variation as is in excess of the universal effect, by the presence of a concentration or cloud of nuclei with net positive charge, which undergoes a very reasonable variation in concentration and effective height.

For one possible mechanism consider a vertical column of air extending upwards from the Earth's surface, with so small cross-section that the density of surface-charge of the Earth as a whole will not be appreciably affected by any change in the air-earth current flowing through the column. If, then, each portion of this column, throughout its height, changes its conductivity by the same proportional amount as a result of a change in the number of nuclei, the air-earth current will vary in a manner similar to that of the conductivity, but these variations will not cause any variation to take place in the potential gradient. Graphs *b* to *e* of Figure 5 do not support such conditions, for they show the potential gradient undergoes variations similar to those of the air-earth current.

[16]Terr. Mag., 32, 31-35 (1927).
[17]Terr. Mag., 34, 281-86 (1929).

For another mechanism consider the vertical column as above described, but with a change in conductivity in only a certain layer of the column, the layer being such that its resistance to the air-earth current is small compared to that of the whole column. For such a layer near the Earth's surface the change in conductivity will result in only a small variation in the air-earth current, while the potential gradient within the layer will vary in an inverse relation to the conductivity. Further assuming that the change in conductivity of the layer is brought about by, and is in inverse relation to, the change in concentration of condensation-nuclei, then at the time when the number of condensation-nuclei is passing through a maximum, the conductivity would be expected to be a minimum, the potential gradient a maximum, and the air-earth current little changed. The observations shown by Figure 5*e* do not support the suggested mechanism, as the negative air-earth current, instead of experiencing little change, undergoes a diurnal variation similar to that of the potential gradient and proportionally about as great.

For a third possible mechanism it is conceivable that there may exist in the air nuclei in considerable concentration at higher altitudes, the concentration as a whole having little or no net charge. The accumulation might be expected to appreciably decrease the total conductivity, that is, increase the total resistance through which the air-earth current must pass. Assuming that at certain times of the day the particles move earthward and many settle out, the measured nuclei-concentration near the Earth's surface would increase while at the same time the total electrical resistance through which the air-earth current must pass might be decreased by the settling out of the particles, thus permitting the air-earth current to increase. The increase in the number of nuclei in a layer of air near the Earth's surface would decrease the conductivity in that stratum, while the potential gradient would, under the circumstances, be increased. Such a mechanism, then, would be associated with an increase in the concentration of condensation-nuclei at the Earth's surface, an increase in the air-earth current and in the potential gradient, but a decrease in the conductivity. Such general relationships among the four elements are actually found (see Figs. 5 and 2). Despite this agreement it is difficult to imagine what would cause the required movement of the large volume of nuclei downward at the warmest time of day. Temperature-effects are apparently ruled out as causes, since they would be expected to produce an upward movement and a decrease in concentration at the Earth's surface rather than the maximum values which are observed at that time. Furthermore, the downward movement of the particles accounts only for the variation from minimum to maximum values of the potential gradient; the change from maximum to minimum would require upward movement of particles and some means of replenishment of the latter to maintain the magnitude of the potential-gradient variations undiminished with time.

If, however, the vertical movement of concentrations or clouds of nuclei is accepted, a fourth mechanism whereby nuclei may be responsible for the diurnal variation of potential gradient can be considered. Assuming that the cloud of nuclei has a net positive charge, it becomes a space-charge, and a simple calculation shows that the observed variation in the potential gradient throughout the day may be accounted

for by a very reasonable variation in the height of a space-charge or cloud of nuclei to which certain dimensions and a certain value of charge are assigned. It was assumed for the calculation that the cloud was of spherical form about 576 meters in diameter, with a volume-density of 0.1 e. s. u. per cubic meter (about 78 per cent of that found at the Earth's surface in the observations of November, 1928) the charge being concentrated at the center of the cloud. It was further assumed that the value of the potential gradient with no charged cloud present would at all times be 75 volts per meter. The calculation showed that at a height of 1.5 kilometer, the cloud would produce a gradient of 20 volts per meter at a point directly below it on the Earth's surface, the total gradient there then being 95 volts per meter. With the height decreased to 0.8 kilometer, the gradient due to the cloud would be increased to 105 volts per meter, bringing about an increase in the observed gradient from 95 to 180 volts per meter. Here again the serious objection is encountered, as in the previous mechanism, that the downward movement is required to be at the warmest time of the day. That an upward movement may be considered—a more reasonable condition—we must assume the cloud is negatively charged, a condition requiring that the potential gradient uninfluenced by the charged cloud exceed the maximum observed value, namely, 180 volts per meter. In view of the values generally observed in regions of known low pollution-content, this hardly seems likely. It would also be difficult to account for the observed increase in the concentration of condensation-nuclei corresponding in time to the increase in height of the negatively charged cloud, except on the basis of more nuclei actually coming into the air at the time. The space-charge graph in Figure 6, from observations on eleven days in November 1928, shows that negative space-charges or negatively charged clouds of nuclei are not usually encountered, at least near the Earth's surface, as it is positive throughout.

If the space-charge, instead of being at a high altitude as in the preceding discussion, is assumed to be near the Earth's surface and to remain fixed in one position, while its charge-density varies (see Fig. 6) in a manner similar to the observed number of nuclei, a fifth mechanism may be considered. If the point at which the potential gradient is being measured is such that the greater part of a positive space-charge is above it, the positive potential gradient will be increased and, furthermore, the variations in the gradient will in general follow the variations in the space charge[18] and in the number of nuclei. The computations for this mechanism assume half the density of the Earth's surface-charge in a region to be induced in consequence of a local space-charge, the other half being considered the normal value for the region. It is further assumed that the local space-charge induces a charge upon a unit of Earth's surface directly below the point of gradient-measurement, ten times as great as that portion of the space-charge existing within a column of air of unit cross-section extending from the unit area of surface up to the gradient measuring-point. The computation showed that if the space-charge density varied by 74 per cent it would produce a variation in the potential gradient of only 35 per cent. In the space-charge measurements during November, 1928, at Washington, the maximum value was about 70 per cent greater than the minimum, while the maximum value of the potential gradient was about 100 per cent greater

[18] J. G. Brown, Terr. Mag., 35, 1-15 (1930).

than the minimum value. It appears possible then to account for only a portion of the observed diurnal-variation of the potential gradient on the basis of a diurnal variation in space-charge operating in the manner outlined.

Thus only the fifth mechanism fits the observed variations in nuclei, conductivity, negative air-earth current, and potential gradient while seeming to meet other reasonable requirements. It indicates that only a portion of the diurnal variation of the potential gradient at Washington can be explained by a change in density of a space-charge. That it may not be necessary to account for more than a portion of the diurnal variation through a local space-charge seems reasonable, since results obtained at both ocean- and land-stations[11] indicate that at least the 24-hour wave varies according to universal time. It seems that the best representation of the variation of potential gradient according to universal time, uninfluenced by local effects, would be that obtained over the ocean. Unfortunately, no ocean-data are available for the dates when the nuclei-observations were made. However, diurnal-variation data on space-charge and potential gradient were obtained at Washington for November 1928, and potential gradient over the ocean was recorded aboard the *Carnegie* during the same month. Three graphs shown in Figure 7*a*, where all are plotted as percentage of average value, suggest by the close similarity between the two for potential gradient that if the one at sea arises from a universal phenomenon, then that at Washington is mainly due to the same cause. However, the two curves differ, and this difference may be explained by a variation in density of a local space-charge and in the height to which it extends. In this case the change in height involves an increase in vertical dimensions of the space-charge concentration, a conception different from that in mechanism four, in which a concentration of constant vertical dimension was changed from one height to another.

The space-charge as measured at Washington was considered as made up of two parts, one part being of universal distribution as the result of that portion of the potential gradient which is a universal phenomenon, the other being of local distribution as the result of a change in the conductivity in an area local with respect to lateral and vertical distribution, of the presence of charged nuclei, etc. The value of the potential gradient will not be affected by the presence of a universal space-charge, but will to some extent depend upon the density and height of the local space-charge. While no definite height can normally be ascribed to the space-charge of the atmosphere since the density of charge in general varies with altitude, that height above the Earth's surface at which the potential gradient would be zero if there were a space-charge of uniform density extending up to this point —the effective height of the space-charge —can be computed and used to advantage. Figure 7*b* shows the diurnal variation in this effective height as calculated from observed values of potential gradient and density of space-charge at Washington during November 1928.

Figure 7*c* shows the difference between the potential gradient at Washington and that over the ocean as recorded on the *Carnegie* for November 1928. Assuming that variation in density as well as in height of the local space-charge at Washington was responsible for the difference in gradient, computations were made of the density of the local space-charge considering it proportional to the difference in gradients

divided by the effective height of the local space-charge. The height of the local space-charge was taken as shown in the computed graph *b* of Figure 7. The computed density of the local space-charge is shown in Figure 7*d*. The character of the diurnal variation in height and in density of a local space-charge required to completely account for the difference in gradients at Washington and over the ocean during November 1928 may readily be accounted for on the basis of a diurnal variation in other factors.

Figure 7*b* also shows the diurnal variation in air-temperature, as obtained from uncorrected thermogram-scalings, at the space-charge observatory. Its similarity to that for space-charge effective height suggests that the variation in temperature plays an important part in determining the height of the local space-charge. The type of curve for the effective height might be expected, assuming that convection-currents set up in the atmosphere—because of the heating of the air near the Earth's surface—carry the surface space-charges up with them. The minor depression in the general maximum in space-charge density perhaps results from rising air-currents, since it is coincident with the maximum in air-temperature.

It seems reasonable that the space-charge at a station where the nuclei-content of the atmosphere is large must be composed largely of charged nuclei. Assuming a constant proportion of the nuclei to be charged positively and a slightly smaller proportion negatively, the diurnal variation in local space-charge density was computed from the mean concentration of condensation-nuclei as obtained during March 1927, 1928, and 1930. Figure 7*d* shows this computed variation and that for the density of the local space-charge for November 1928, the latter computed on a different basis. Since two entirely different methods of analysis were used, the close similarity of the graphs supports the conclusion that the main features of the variation in local space-charge density may be satisfactorily explained through a variation in concentration of condensation-nuclei.

Figure 7*c* gives the diurnal variation in the difference of potential gradient at Washington and over the ocean for November 1928. As a secondary minimum occurs during the warmest part of the day, the product of effective height and density of local space-charge (being considered proportional to the difference in gradient) likewise has a secondary minimum occurring at this time. This secondary minimum takes place in spite of the fact that the effective height passes through a maximum at this time and consequently is due to a secondary minimum in the density of space-charge. This secondary minimum in the density of the local space-charge appears to be associated, as has already been suggested, with the convection-currents occurring at the time. A similar phenomenon is observed at many land-stations, where a secondary minimum in potential gradient tends to develop during the warmest time of the day; this is most pronounced during the warm seasons and tends to disappear during the cold seasons. Thus it seems possible that convection-currents may cause this secondary minimum. In view of the small daily range in air-temperatures over the ocean, a similar secondary minimum for potential-gradient at sea, on the assumption that it is caused by convection-currents, is not to be expected. Mauchly,[11] discussing *Carnegie* data, combined five pairs of potential-gradient diurnal-variation series where the longitude-difference for each pair was

about 180°. Any depression of appreciable magnitude, varying according to local time, would have been revealed by this method of treatment, but Mauchly's curve, while not entirely without irregularities, shows no variation of this type. This supports the theory that the secondary minimum observed during the warmest part of the day at many land-stations is due to convection-currents.

SUMMARY

(1) Concentration of condensation-nuclei shows no correlations with any of the meteorological elements except temperature and relative humidity, and the results suggest these elements are not large factors in determining the number of nuclei present.

(2) The diurnal-variation graphs for the computed rate of ionization (q) on the basis of the linear recombination-law, are similar to those for the negative air-earth current computed from the product of the potential gradient and the negative conductivity; other considerations, however, indicate this variation of q may not be regarded as the cause of the variation in the negative air-earth current.

(3) Hourly values of the negative conductivity calculated, assuming a constant value of q, from observed hourly values of the concentration of condensation-nuclei, by means of the linear-recombination equation and by means of the square-root equation, show that either equation gives fair agreement with observed values.

(4) Several mechanisms to account for the diurnal variation in potential gradient at Washington through the observed variation in the number of condensation-nuclei, charged or uncharged, are discussed. In view, however, of the known universal character of the diurnal variation of the potential gradient, it seems possible to explain only a portion of the diurnal variation through such mechanisms; experimental results show this portion may be entirely explained through a variation in the height and in the density of a local space-charge, the necessary variation in height being satisfactorily explained through convection-currents, and that in density through a variation in the number of condensation-nuclei.

(5) Experimental evidence supports the theory that the secondary minimum in the diurnal variation of the potential gradient, occurring at many land-stations during the warmest time of the day, is produced through the mechanism of convection-currents in the atmosphere.

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NOTES

(See also pages 98 and 149)

11. *Two new polar periodicals*—The interest awakened in polar exploration by the finding of the remains of Andrée's ill-fated balloon expedition of 1897, and the proposed Jubilee Polar Year 1932-1933 for international coöperative investigation of the polar regions on a grand scale, has called forth a number of important publications. Among the more recent ones are two periodicals devoted entirely to matters pertaining to polar research. *The Polar Record* is published by the Scott Polar Research Institute, of Cambridge, England, and is to appear semiannually. At first an attempt will be made merely to record the chief polar events of the preceding six months, but it is expected that the scope of the journal will gradually be extended. The editors hope to present an outline of polar endeavor such as is not otherwise accessible to those not in a position to consult foreign literature, press articles, etc. In the first number considerable concise information regarding recent work in both the arctic and antarctic regions is given. A bibliography of recent pertinent literature concludes the number. The *Bulletin of the Arctic Institute*, of Leningrad, is to be published monthly by an editorial board consisting of N. W. Pineguin, R. L. Samoilovich, O. J. Schmidt, W. J. Wiese, and W. K. Yessipov. About three-fourths of the first (double) number is in Russian and the remainder in English. The bulletin will contain: Information on general problems connected with the polar regions; activities of the Arctic Institute and other organizations working in the North; Soviet expeditions to the arctic; foreign exploratory expeditions in the arctic and antarctic; activity of polar stations; reports of scientific societies and public organizations; survey of literature; reviews; and lists of new publications.

12. *Wilkins-Ellsworth Trans-Arctic Submarine Expedition*—The arctic submarine *Nautilus*, commanded by Captain Sir Hubert Wilkins, is planned to leave Bergen in June on its undersea journey across the polar regions, in the course of which geophysical investigations are planned, including particularly a full program of terrestrial magnetism and oceanography. At Bergen the party is to be joined by Dr. H. U. Sverdrup, chief of the scientific staff, research associate in geophysics of the Christian Michelsen Institute of Bergen and research associate of the Carnegie Institution of Washington; Floyd M. Soule, observer in the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, who has acquired experience in investigations of terrestrial magnetism and of physical oceanography on Cruise VII of the *Carnegie*, and Dr. Bernhard Villinger, of Freiburg im Breisgau, whose wide experience as a physician in the World War and participation in two previous arctic expeditions especially fit him for taking part in the present enterprise. At Bergen scientific equipment is to be installed, including that for complete magnetic and astronomical observations on the ice-floes, a Vening-Meinesz gravity-apparatus, a spectrograph, full equipment of oceanographic apparatus and appurtenances (a winch for deep-sea work, fathometer, complete radio receiving and transmitting outfit, and other instruments had already been installed in the United States).

13. *Aeroarctic trial polar flight*—The *Graf Zeppelin*, under the command of Dr. Hugo Eckener, is scheduled to leave Germany on July 10, for a trial flight in the arctic regions, preparatory to possible participation in the scientific program of the International Polar Year 1932-1933. The immediate object of the present flight is the testing under flying conditions of scientific instruments designed and prepared by various specialists in geophysics in view of future scientific investigatory work of the Aeroarctic in the North. Lieutenant-Commander Edward H. Smith, of the United States Coast Guard, who has acquired expert knowledge on the subject of icebergs and their movements through his long association with the Coast Guard's North Atlantic Ice Patrol, has been assigned to participate in the expedition as the representative of the American section of Aeroarctic.

ON PULSATIONS OF TERRESTRIAL MAGNETISM AND THEIR POSSIBLE EXPLANATION BY PERIODIC ORBITS OF CORPUSCULAR RAYS

By Carl Störmer

(1) In a paper published in 1906[1] I suggested as a possible explanation of the terrestrial-magnetic disturbance called "Eschenhagens Elementarwellen" the action of clouds of electric corpuscles moving along periodic orbits in space far away from the Earth.

A rough calculation of the periods from certain types of calculated orbits gave periods of the same order as those observed, and the fact that these waves are a phenomenon which occurs simultaneously all over the Earth[2] seems to indicate that their origin must lie far out in space and must be of a cosmical nature.

I am grateful to the Norwegian foundation "Statens Videnskabelige Forskningsfond av 1919" for having made grants for several consecutive years to resume the numerical integrations which were used by my assistants and myself in the years 1904-1907 to calculate orbits of electric corpuscles in the Earth's magnetic field in space.[3]

Thanks to these grants a large program is now outlined to get a general survey of all possible orbits with applications to the polar aurora, to magnetic disturbances, to the echoes from electromagnetic short-waves, to the penetrating-radiation, and so on.

Last year the first step was made by calculating a long series of *periodic* orbits. A report[4] on this work was published in *Zeitschrift für Astrophysik* in 1930. I had a most interesting collaboration with the young German physicist Dr. Ernst Brüche, who succeeded in reproducing experimentally most of the calculated orbits and also found by experiment some new ones not yet calculated. An extract of Brüche's work is given by him in this Journal.[5]

It may interest the readers of this Journal to see some more details on the computed periods of these periodic corpuscular orbits in space outside the Earth for possible comparison with observed facts. My theory that the magnetic pulsations are actions from clouds of electric corpuscles coming from the Sun and moving for some time in the vicinity of such periodic orbits is of course only to be considered as a working hypothesis, and I have not had opportunity myself to study the great amount of existing observational material on Eschenhagen waves. It is to be hoped that during the coming International Polar Year of 1932–33 much new valuable material may be collected by simultaneous rapid photographic registrations all over the world.

(2) We will not discuss here the mathematical theory of these periodic orbits, but will give only the results.

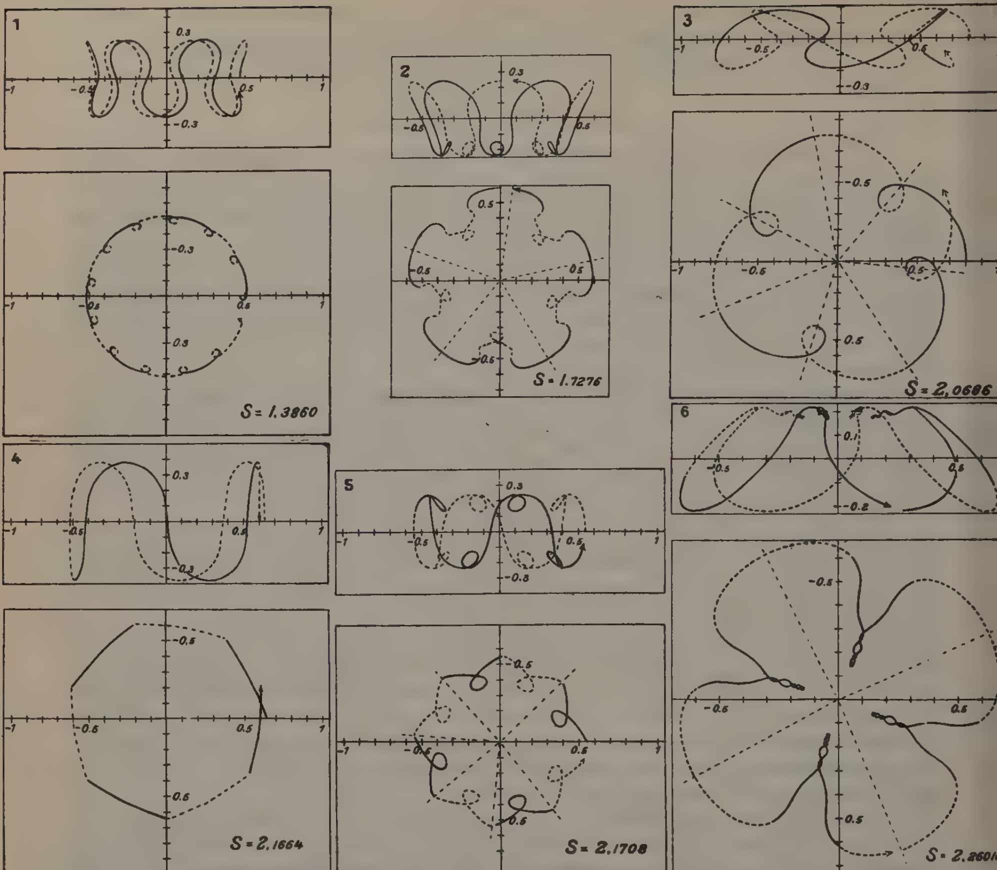
[1] On the trajectories of electric corpuscles in space under the influence of terrestrial magnetism applied to the aurora borealis and to magnetic disturbances. Arch. Math. Naturv., Kristiania, **28**, No. 2 (1906).

[2] Kr. Birkeland, Expédition Norvégienne de 1899-1900 pour l'étude des aurores boréales. Kristiania, Skr. Vid. selsk., No. 1 (1901). G. Angenheister und J. Bartels, Das Magnetfeld der Erde. Wien-Harms Handbuch der Experimentalphysik, **25**, I, 667 (1928).

[3] C. Störmer, Résultats des calculs numériques des corpuscles éléctriques dans le champ d'un aimant élémentaire. Kristiania, Skr. Vid. selsk., Nos. 4, 10, and 13 (1913).

[4] C. Störmer, Periodische Elektronenbahnen im Felde eines Elementarmagneten und ihre Anwendung auf Brüches Modellversuche und auf Eschenhagens Elementarwellen des Erdmagnetismus. Zs. Astroph., **1**, 237-274 (1930).

[5] E. Brüche, Some new theoretical and experimental results on the aurora polaris. Terr. Mag., **36**, 41-52 (1931).



Figs. 1–6

The majority of the calculated periodic orbits are reproduced in the Figures 1 to 12. The simplest of them all, the circular orbit, is shown as No. 11. Of these orbits, numbers 1, 2, 3, 4, 5, 7, 9, and 11 have been verified experimentally by Dr. Brüche. Each Figure indicates in the lower part the projection of the orbit on the *XY*-plane and in the upper part the projection on the *XZ*- or *YZ*-plane. The elementary magnet representing the Earth is at the origin of the system of coördinates with its axis along the *Z*-axis, the south pole pointing upwards; in other words, the *Z*-axis represents the magnetic axis of the Earth and in the arctic regions points in the direction of positive *Z* (upwards). The *XY*-plane is the magnetic equatorial plane, that is, the plane through the center of the Earth normal to the magnetic axis.

The unit of length is $(Me/mv)^{1/2}$ cm, in which $M = 8.4 \times 10^{25}$ is the magnetic moment of the Earth, v is the velocity in centimeters per second of the corpuscle and (m/e) is the ratio between the mass and charge of the corpuscle in electromagnetic units. For negative cor-

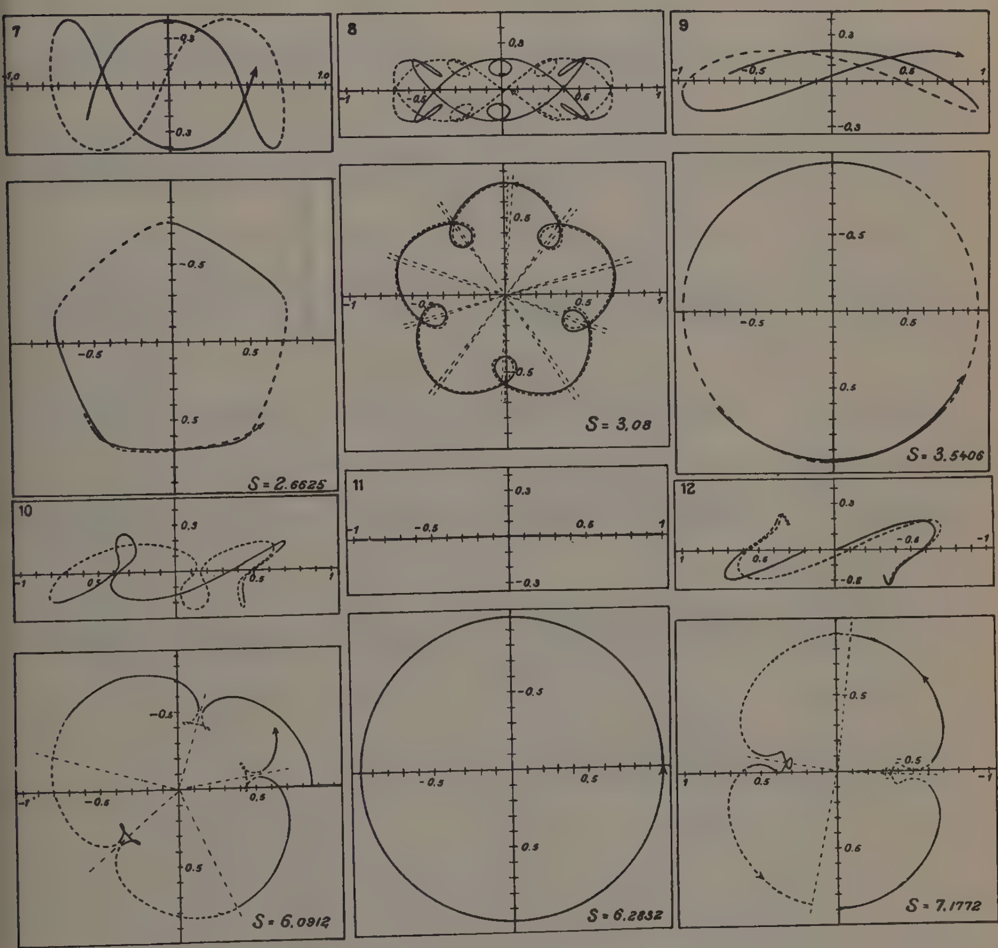
puscles the motion takes place round the Earth from south through east to north and for positive corpuscles in the opposite direction.

On each Figure is written the period S, that is, the length of the periodic part of the orbit from one point to the next one, where the same loop begins again. This period is measured in the above adopted unit of length.

(3) The time T in seconds needed for the corpuscle to move along the periodic part S of the trajectory is given by

$$T = (Me/mv)^{1/2}\ (S/v)$$

and this period is to be compared with the observed periods of the Eschenhagen waves. We will give the well-known formulae[6] necessary for this calculation.



Figs. 7–12

[6]See for instance H. Geiger, Elektrone, Atome, Moleküle, Handbuch der Physik, 22 (1926).

TABLE 1—*Elements and periods for periodic orbits*

V	10	10^2	10^3	10^4	10^5	10^6	10^7	10^8	10^9	10^{10}
v in cm/sec	1.88×10^8	5.94×10^8	1.88×10^9	5.86×10^9	1.65×10^{10}	2.82×10^{10}	3×10^{10}	3×10^{10}	3×10^{10}	3×10^{10}
β	0.00626	0.0198	0.0625	0.195	0.549	0.941	0.9986	1	1	1
$3\times10^{10}-v$	2.98×10^{10}	2.94×10^{10}	2.81×10^{10}	2.41×10^{10}	1.35×10^{10}	1.76×10^9	3.53×10^7	3.86×10^5	3890	38.9
$H\rho$	10.6	33.6	106	338	1120	4740	3.50×10^4	3.35×10^5	3.34×10^6	3.33×10^7
$\sqrt{M/H\rho}$	2.81×10^{12}	1.58×10^{12}	8.88×10^{11}	4.98×10^{11}	2.74×10^{11}	1.33×10^{11}	4.90×10^{10}	1.58×10^{10}	5.02×10^9	1.59×10^9
Orbit No.	Computed period T in seconds									
1	20,700	3,690	656	118	23.1	6.54	2.26	0.732	0.232	0.0733
2	25,800	4,590	818	147	28.8	8.15	2.82	0.912	0.289	0.0914
3	30,900	5,500	979	176	34.5	9.76	3.38	1.09	0.346	0.109
4	32,400	5,760	1,030	184	36.1	10.2	3.54	1.14	0.362	0.115
5	32,500	5,770	1,030	185	36.2	10.2	3.55	1.15	0.363	0.115
6	33,800	6,010	1,070	192	37.7	10.7	3.70	1.19	0.378	0.120
7	39,800	7,080	1,260	227	44.4	12.6	4.35	1.41	0.445	0.141
8	46,000	8,190	1,460	262	51.3	14.5	5.04	1.63	0.515	0.163
9	52,900	9,410	1,680	301	59.9	16.7	5.79	1.87	0.592	0.187
10	91,100	16,200	2,880	518	102	28.7	9.96	3.22	1.02	0.322
11	93,900	16,700	2,974	534	105	29.6	10.3	3.32	1.05	0.332
12	107,000	19,100	3,400	611	120	33.8	11.7	3.79	1.20	0.380

TABLE 2—*Elements and periods for periodic orbits*

V	10^4	2×10^4	3×10^4	4×10^4	5×10^4	6×10^4	7×10^4	8×10^4	9×10^4
v in cm/sec	5.86×10^9	8.17×10^9	9.86×10^9	1.12×10^{10}	1.21×10^{10}	1.34×10^{10}	1.43×10^{10}	1.51×10^{10}	1.58×10^{10}
β	0.195	0.272	0.329	0.374	0.413	0.447	0.477	0.503	0.527
$H\rho$	338	481	591	686	771	848	920	988	1053
$\sqrt{M/H\rho}$	4.98×10^{11}	4.18×10^{11}	3.77×10^{11}	3.50×10^{11}	3.30×10^{11}	3.15×10^{11}	3.02×10^{11}	2.91×10^{11}	2.82×10^{11}
Orbit No.	Computed period T in seconds								
1	118	71	53	43	37	33	29	27	25
2	147	88	66	54	46	41	37	33	31
3	176	106	79	64	55	49	44	40	37
4	184	111	83	67	58	51	46	42	39
5	185	111	83	68	58	51	46	42	39
6	192	116	86	70	60	53	48	44	40
7	227	136	102	83	71	63	56	51	48
8	262	158	118	96	82	72	65	60	55
9	301	181	135	110	94	83	75	68	63
10	518	312	233	190	162	143	129	118	109
11	535	322	240	196	167	148	133	122	112
12	611	367	274	224	191	169	152	139	128

TABLE 3—*Elements and periods for periodic orbits*

V	10^5	2×10^5	3×10^5	4×10^5	5×10^5	6×10^5	7×10^5	8×10^5	9×10^5
v in cm/sec	1.65×10^{10}	2.09×10^{10}	2.33×10^{10}	2.48×10^{10}	2.59×10^{10}	2.66×10^{10}	2.72×10^{10}	2.76×10^{10}	2.80×10^{10}
β	0.549	0.695	0.777	0.828	0.863	0.888	0.907	0.921	0.932
$H\rho$	1,120	1,650	2,100	2,510	2,910	3,230	3,660	4,020	4,380
$\sqrt{M/H\rho}$	2.74×10^{11}	$2\ 26\times10^{11}$	2.00×10^{11}	1.83×10^{11}	1.70×10^{11}	1.60×10^{11}	1.52×10^{11}	1.44×10^{11}	1.39×10^{11}
Orbit No.	Computed period T in seconds								
1	23	15	12	10	9	8	8	7	7
2	29	19	15	13	11	10	10	9	9
3	34	22	18	15	14	12	12	11	10
4	36	24	19	16	14	13	12	11	11
5	36	23	19	16	14	13	12	11	11
6	38	24	19	17	15	14	13	12	11
7	44	29	23	20	17	16	15	14	13
8	51	33	26	23	20	18	17	16	15
9	59	38	30	26	23	21	20	19	18
10	102	66	52	45	40	37	34	32	30
11	105	68	54	46	41	38	35	33	31
12	120	78	62	53	47	43	40	38	36

TABLE 4—*Elements and periods for periodic elements*

V	10^6	2×10^6	3×10^6	4×10^6	5×10^6	6×10^6	7×10^6	8×10^6	9×10^6
v in cm/sec	2.82×10^{10}	2.94×10^{10}	2.97×10^{10}	2.98×10^{10}	2.99×10^{10}	2.99×10^{10}	2.99×10^{10}	2.99×10^{10}	3×10^{10}
β	0.941	0.979	0.989	0.994	0.996	0.997	0.998	0.998	0.999
$H\rho$	4,740	8,190	11,600	14,900	18,300	21,600	25,000	28,300	31,700
$\sqrt{M/H\rho}$	1.33×10^{11}	1.01×10^{11}	8.52×10^{10}	7.50×10^{10}	6.78×10^{10}	6.23×10^{10}	5.80×10^{10}	5.45×10^{10}	5.15×10^{10}
Orbit No.	Computed period T in seconds								
1	7	5	4	3	3	3	3	3	2
2	8	6	5	4	4	4	3	3	3
3	10	7	6	5	5	4	4	4	4
4	10	7	6	5	5	5	4	4	4
5	10	7	6	5	5	5	4	4	4
6	11	8	6	6	5	5	4	4	4
7	13	9	8	7	6	6	5	5	5
8	15	11	9	8	7	6	6	6	5
9	17	12	10	9	8	7	7	6	6
10	29	21	17	15	14	13	12	11	10
11	30	22	18	16	14	13	12	11	11
12	34	25	21	18	16	15	14	13	12

We have for electrons

$$e/m_0 = 1.766 \times 10^7 \text{ electromagnetic units}$$
$$m = m_0/(1 - \beta^2)^{1/2} \text{ gram}$$

where $m_0 = 9.003 \times 10^{-28}$ gram and where $\beta = v/3 \times 10^{10}$ is the ratio between the velocity of the electron and the velocity of light.

On the other hand, if we introduce the potential V volt, in technical units, the velocity v corresponding to this potential or what is the same, the corresponding value β is given by the equation

$$eV/300 = 3 \times 10^{10}\ m_0[1/(1 - \beta^2)^{1/2} - 1]$$

If we introduce

$$w = 1 + (e/3 \times 10^{10} m_0)\ (V/300)$$

then

$$v = 3 \times 10^{10}\ [\ (w^2 - 1)^{1/2}/w]$$

and

$$(m/e)v = 3 \times 10^{10}(m_0/e)\ (w^2 - 1)^{1/2}$$

which permits, for a given value of V, the calculation of v.

This product $(m/e)v$ has another very useful meaning, namely, if the electron is moving normally to the lines of force in a homogeneous magnetic field of strength H, it moves in a circle with radius ρ centimeters and we have $(m/e)v = H\rho$. For α-particles from the radioactive elements we have, if the charge is E electromagnetic units and m is the mass

$$E/m = 4823$$

and v has values between 1.4×10^9 and 2.06×10^9 centimeters per second.

My assistant, Mr. Anda, has calculated from these formulae the following Tables 1 to 4 for electrons corresponding to different potentials. The calculation has been made with more significant figures, but only three are given in these Tables. The numbers 1 to 12 refer to the different periodic orbits in Figures 1 to 3, and the corresponding periods are given in seconds for Table 1 to three significant figures and in Tables 2 to 4 to nearest whole second.

The periods corresponding to α-rays are given in Table 5.

Table 5—*Periods in seconds corresponding to α-rays*

v	$H\rho$	$\sqrt{M/H\rho}$	Periodic orbit No.											
			1	2	3	4	5	6	7	8	9	10	11	12
1.4×10^9	290,000	1.70×10^{10}	17	21	25	26	26	27	32	37	43	74	76	87
2.06×10^9	427,000	1.40×10^{10}	9	12	14	15	15	15	18	21	24	41	43	49

For pulsations with periods of some minutes, electrons corresponding to V less than 10^3 and greater than 10^6 are probably excluded.

There are, however, an infinite number of more complicated periodic orbits which have not here been considered, and the periods of the orbits merge continuously in each other, as do the orbits themselves.

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THE LUNAR-DIURNAL MAGNETIC VARIATION IN RELATION TO THE GEOGRAPHIC AND MAGNETIC EQUATORS

By J. Egedal

In an article in the Ad. Schmidt-Festschrift[1] it has been stated that a representation of the field of the solar-diurnal magnetic variation ought to contain magnetic as well as geographic coördinates, since the solar-diurnal variation depends on magnetic latitude of the place of observation. Now it will be shown also that the lunar-diurnal magnetic variation depends on the magnetic latitude of the place of observation.

Reckoning the declination positive towards east, the lunar-diurnal variation for the northern hemisphere is given approximately by

$$l \sin (2t + 270°) \tag{1}$$

where l is the amplitude and t the lunar hour-angle. For the southern hemisphere the lunar-diurnal variation is given by

$$l \sin (2t + 90°) \tag{2}$$

Up to the present it has not been possible to say whether the change of 180° in the phase-angle takes place at the geographic equator or at the magnetic equator (where the magnetic vertical intensity Z is zero). This problem is solved when the lunar-diurnal variation is determined for a place lying between the two equators.

When the corresponding question for the solar-diurnal variation was investigated the observations from Pará, South America, were used, and in our case the same observations[2] can be utilized. The lunar-diurnal variation of the magnetic declination is used as indicator. The variation has been determined for a certain hour of the day (10^h a. m., local time) by means of the method given by van der Stok.[3] All observations made at Pará from September 1882 to November 1883—in total, 328—were used.

In Table 1 departures from the mean of easterly declination for different lunar hours are given.

From the departures it is found that the lunar-diurnal variation for Pará contains the following main term[4]

$$0'.33 \sin (2t + 272°) \tag{3}$$

and the mean error of the amplitude is $\pm 0'.05$. From (3) it is seen that the lunar-diurnal variation for Pará corresponds to the lunar-diurnal variation for the northern hemisphere (1), although Pará is in the southern hemisphere (latitude 1° 27′ south). In using the magnetic equator as line of separation, it is found that all lunar-diurnal varia-

[1] J. Egedal, Über die Herleitung des Potentials des täglichen erdmagnetischen Variationsfeldes. Zs. Geophys., **6**, 263-265 (1930).

[2] E. van Rijckevorsel and E. Engelenburg. Magnetic survey of the Eastern Part of Brazil. Amsterdam, Nat. Verh. K. Akad. Wet., **27**, (1890).

[3] Batavia, Obsns. Magn. Meteor., **9**, App. 2, p. 12.

[4] From Batavia Obsns. Magn. Meteor. **26**, 220-221 (1903), it is seen that the mean amplitude found at Batavia for 10^h a. m. is of the same magnitude as the amplitude found for Pará.

TABLE 1—*Departures from the mean of easterly declination for different lunar hours at Pará, September 1882 to November 1883 at* 10^h *a. m.*

Lunar hour	Departure	Lunar hour	Departure
h	′	h	′
24.0	−0.44	12.0	−0.22
23.2	−0.99	11.2	−0.42
22.4	−0.13	10.4	−0.36
21.6	−0.66	9.6	−0.10
20.8	0.63	8.8	0.17
20.0	0.58	8.0	0.41
19.2	0.03	7.2	0.53
18.4	−0.65	6.4	0.46
17.6	0.33	5.6	0.40
16.8	0.27	4.8	0.76
16.0	−0.09	4.0	−0.40
15.2	−0.03	3.2	0.28
14.4	0.18	2.4	0.20
13.6	−0.45	1.6	−0.21
12.8	−0.22	0.8	0.18

tions in each of the two magnetic hemispheres are of the same type. The result of the present investigation is therefore similar to the result obtained by the corresponding investigation on the solar-diurnal variation, namely, that not only the geographic equator, but also the magnetic equator is of importance with respect to the distribution of the field of the lunar-diurnal variation. Therefore in representing the field of the magnetic variations it is necessary also to use geomagnetic coordinates.

The observations at Pará were made in connection with the first International Polar Year, and it is to be hoped that the interesting results obtained from this observatory may emphasize the desirability of reoccupying the station in the Second International Polar Year. Then valuable observations of the magnetic variations for the areas between the geographic and the magnetic equators could be obtained from two well-placed magnetic observatories, namely, Huancayo and Pará.

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AMERICAN *URSI* BROADCASTS OF COSMIC DATA[1]

Summary American URSI daily broadcasts of cosmic data, February to April, 1931

February

Day	Magnetism Char.	Magnetism Type	G. M. T. begin. distur. h	G. M. T. begin. distur. m	Sun-spot Groups	Sun-spot No.	Solar constant Value (cal)	Solar constant Char.
1	0		22		0	0		
2	1	*o*			1	2		
3	0						1.923	*u*
4	0							
5	0						1.935	*f*
6	0							
7	0							
8	0							
9	0				4	18	1.948	*f*
10	0							
11	0						1.946	*f*
12	0						1.944	*s*
13	1	*p*	9	00			1.946	*s*
14	2	*p*					1.947	*s*
15	1	*o*					1.954	*f*
16	1	*p*			5	13		
17	0				5	28		
18	0				3	24	1.939	*f*
19	0				3	24	1.943	*f*
20	0				3	16	1.940	*f*
21	0				3	23	1.948	*f*
22	0						1.943	*f*
23	0						1.940	*s*
24	1	*i*	5	30	4	31	1.939	*s*
25	1	*i*	17		6	40	1.939	*f*
26	2	*i*			7	32	1.939	*f*
27	1	*b*	7	50	5	33	1.920	*u*
28	0				4	22		
29								
30								
31								
Mean	0.4				3.8	21.8	1.941	

March

Day	Magnetism Char.	Magnetism Type	G. M. T. begin. distur. h	G. M. T. begin. distur. m	Sun-spot Groups	Sun-spot No.	Solar constant Value (cal)	Solar constant Char.
1	0				3	17	1.922	*u*
2	0				3	25		
3	1	*o*			2	22	1.937	*f*
4	0				2	23	1.923	*u*
5	0				2	25		
6	0				2	20		
7	0				2	20		
8	0				2	18	1.933	*f*
9	0				3	15	1.925	*f*
10	0				2	26	1.931	*f*
11	1	*p*			2	21	1.941	*f*
12	0						1.941	*f*
13	1	*p*			3	28	1.947	*f*
14	1	*o*			3	20	1.941	*f*
15	0				3	20	1.942	*f*
16	0				4	16	1.939	*f*
17	0				4	16	1.950	*s*
18	0				5	32	1.944	*f*
19	0				5	21	1.957	*f*
20	0		16	25	4	25	1 948	*f*
21	1	*i*	20	30			1.951	*s*
22	1	*o*			3	3	1.944	*s*
23	1	*b*	3	40	2	4	1.949	*s*
24	0						1.950	*s*
25	1	*b*	7	40	1	1	1.944	*s*
26	1	*b*	0	30	1	1	1.945	*f*
27	0				1	6	1.946	*s*
28	0						1.943	*f*
29	0				1	3	1.950	*s*
30	0				2	5	1.956	*s*
31	0				3	8	1.951	*f*
Mean	0.3				2.6	16.3	1.943	

April

Day	Magnetism Char.	Magnetism Type	G. M. T. begin. distur. h	G. M. T. begin. distur. m	Sun-spot Groups	Sun-spot No.	Solar constant Value (cal)	Solar constant Char.
1	0				4	13	1.952	*f*
2	0				5	8	1.949	*s*
3	0				3	5	1.950	*s*
4	0				4	10	1.943	*s*
5	0						1.951	*s*
6	0				3	16		
7	0				3	24	1.948	*f*
8	0				3	17		
9	0				3	37	1.950	*s*
10	1	*i*	3		3	26	1.944	*s*
11	1	*i*			4	26	1.950	*s*
12	0				5	13	1.952	*s*
13	0				4	11		
14	0				3	18	1.949	*f*
15	0				3	13	1.950	*f*
16	0				3	8	1.950	*f*
17	0				4	30	1.941	*f*
18	1	*i*			2	12		
19	0		15		2	10		
20	1	*i*			3	10	1.944	*s*
21	0				3	17	1.921	*f*
22	1	*i*					1.927	*f*
23	0							
24	0							
25	0						1.937	*f*
26	1	*i*					1.945	*s*
27	0						1.938	*s*
28	0				2	2	1.952	*s*
29	0						1.948	*f*
30	0				2	4		
31								
Mean	0.2				3.2	15.0	1.945	

Greenwich mean time for endings of storms: 10^h, Feb. 2; 2^h, Feb. 16; 3^h, Feb. 25; 8^h, Feb. 26; 9^h, Feb. 27; 8^h, Mar. 22; 4^h 50^m, Mar. 23; 9^h 20^m, Mar. 25; 1^h 40^m, Mar. 26; 8^h, April 22.

The first three columns of the Table give (1) the magnetic character according to the scale 0-2 of the International Commission of Terrestrial Magnetism and Electricity, (2) the type featuring the day other than normal by the letters *b*, *p*, *o*, and *i* for days marked by bay, rapid pulsations, long-period oscillations, and irregular oscillations, respectively, and (3) the hour and minute of Greenwich mean time marking the beginning of a storm, the end of the storm being indicated in the footnote to the Table. The next two columns give the data relating to sunspots: (1) the number of groups of spots and (2) the total number of spots. It is to be noted that sunspot-numbers such as those from Zürich can be obtained from the number of groups and spots given in the Table by the formula $N = k\,(10g + s)$, where k for Mount Wilson is about 0.77. The sixth and seventh columns show (1) the value in calories of the solar constant, and (2) by letters *s*, *f*, and *u* whether the determination was satisfactory, fair, or unsatisfactory, respectively.

KATHARINE B. CLARKE

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON,
Washington, D. C.

[1]For previous announcements see Terr. Mag., **35**, 184-185 and 252-253 (1930); **36**, 54 (1931).

PROVISIONAL SUNSPOT-NUMBERS FOR MARCH AND APRIL, 1931

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	Mar.	Apr.	Day	Mar.	Apr.
1	*E*34[c]	34[d]	17	*W*51[c]	41
2	31	32	18	49[a]	22
3	24[a]	29	19	38	20[a]
4	..	..	20	40	20
5	..	*E*25[c]	21	26	*W*38[c]
6	..	31	22	25	41
7	28[a]	40[a]	23	26	27
8	.	44	24	10[a]	*M*29[c]
9	32[d]	45	25	8	37
10	32	29[a]	26	8	21
11	38	36[d]	27	8	19
12	38	36	28	14	14
13	43[d]	44[a]	29	16	*W*17[c]
14	47	38	30	9	18
15	46[b]	37	31	*WE*27[cc]	..
16	41	31[a]			
			Means	29.1	30.9
			No. days	27	29

Mean for the quarter January to March, 1931: 28.4 (75 days)

aPassage of an average-sized group through the central meridian.

bPassage of a larger group through the central meridian.

cNew formation of a large or average-sized center of activity: *E*, on the eastern part of the Sun's disc; *W*, on the western part; *M*, in the central zone.

dEntrance of a large or average-sized center of activity on the east limb.

Zürich, Switzerland W. Brunner

PROVISIONAL SOLAR AND MAGNETIC CHARACTER-FIGURES, MOUNT WILSON OBSERVATORY, JANUARY TO MARCH, 1931[1]

Three moderate magnetic storms were recorded in the months of January and February. During the first storm, January 16 to 18, an active group in north latitude 8° was near the west limb. This group had been especially active on January 15. At the beginning of the second storm, February 13 to 16, no solar observations were possible at Mount Wilson. During the third storm, February 24 to 27, a large group in north latitude 7° was near the west limb. This group was most active during the magnetically calm days between the two storms in February. In March the Earth's magnetic field was relatively calm. On March 20 at 16^h 24^m the intensity and direction of the horizontal component changed suddenly by a very moderate amount.

The number of groups of sunspots observed daily, given in these tables, may differ from those transmitted daily to *Science Service* for the broadcast of cosmic data, because the latter are telephoned from the Observatory as soon as the observations are made, while those given here are assigned after the spots have been classified and grouped according to their magnetic behavior.

[1]For previous tabulations from November 1929, see Terr. Mag., **35**, 47-49, 92, and 249-251 (1930), and **36**, 55-56 (1931).

Day	January, 1931								February, 1931								March, 1931							
	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.
	A	*B*	*A*	*B*	*A*	*B*			*A*	*B*	*A*	*B*	*A*	*B*			*A*	*B*	*A*	*B*	*A*	*B*		
1	...	...	...	...	...	...	...	0	0	0	0	0	1	0	0	0	2	2	2	2	1	1	3	0
2	...	...	...	...	...	...	...	0	...	...	...	...	...	...	1	0.5	2	1	2	2	1	1	2	0
3	0	0.5	0	0.5	1	0	0	0	...	...	...	...	...	...	...	0.5	2[d]	2[d]	2	2	1	1	2[e]	1.0
4	0	0	...	...	...	...	2	0	...	...	...	...	...	...	...	0	2[d]	2[d]	2	2	0	0	2	0
5	0.5	0	0.5	0	1	0	2	0	...	...	...	...	...	...	...	0	2	2	2	2	1	1	2	0
6	0.5	0	0.5	0	1	0	2	...	...	...	...	...	...	...	...	0	2	1	2	1	1	1	2	0
7	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	1	1	2	1	1	0	2	0
8	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	0	1	1	1	2	1	0	3	0.5
9	...	...	...	...	...	...	...	0.5	1	1	1	2	1	0	4	0	1	1	1	1	1	0	3	0
10	1	2	2	3	2	3	1	0.5	...	...	...	...	...	...	...	0	1	0	1	0	1	0	3	0.5
11	1	2	2	3	2	2	2	0	...	...	...	...	...	...	...	...	1	0	1	0	1	2	3	0
12	1	1	1	1	2	1	2	0	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	0.5
13	...	...	...	...	...	...	3	0	...	...	...	...	...	...	...	1.5	1	1	1	1	1	1	3	1.0
14	...	...	...	...	...	...	4	0	...	...	...	...	...	...	...	1.0	2	2	2	2	1	1	3	0.5
15	1	0.5	2[a]	0	2	0	3	0	...	...	...	...	...	...	5	1.0	2	2	2	2	2	1	3[f]	0
16	1	0.5	1.5[a]	0	1	1	2	1.0	...	...	...	...	...	...	5	0.5	2	2	2	2	2	2	4	0
17	1	1	1	0.5	1	2	2	1.0	2	1	2	1	1	1	3	0	2	1	2	2	1	1	6	0
18	1	1.5	1	2	1	0	2	1.0	2	1	2	1	2	1	3	0	2	2	2	2	1	1	6	0
19	1	2	1	2	2	2	2	0.5	2	2	2	2	2	1	4	0	2	3	2	3	1	1	5	0
20	1	2	2	2	2	2	2	0	2	2	2[b]	2[b]	2	1	3[c]	0	2	2	2	3	1	1	5	0.5[g]
21	1	1	1	1	2	2	2	0	2	2	2[b]	2[b]	1.5	1	3	0	2	2	2	2	1	1	3	0.5
22	1	1	2	1	2	1	2	0.5	2	2	2	2	1.5	1	5	0	2	1	...	...	...	...	3	0.5
23	...	...	...	...	...	...	...	0	2	0	2	0	1	0	5	0	1	1	1	1	1	0	3	0.5
24	1	1	1.5	1	2	1	2	0	2	1	2	1	1	0	4	1.0	...	...	...	...	...	...	...	0
25	...	...	...	...	...	...	2	0.5	2	1	2	1	1	0	6	1.0	1	1	...	...	...	...	1	0.5
26	0.5	0.5	0.5	0.5	2	0	1	0.5	2	1	2	1	1	0	8	1.0	1	0	...	...	...	...	1	0.5
27	1	1	...	...	...	...	0	0.5	...	...	...	...	...	...	5	0.5	1	0	1	0	1	1	1	0.5
28	0.5	1	1	1	1	0	1	0.5	1	1	2	1.5	1	1	4	0	...	...	...	...	...	...	...	0
29	0.5	0.5	0.5	0.5	1	0	0	0.5									1	1	1	1	1	1	2	0
30	...	...	...	...	...	...	...	0									1	1	1	1	1	1	4	0
31	...	...	...	...	...	...	...	...									1	2	1	2	1	1	3	0
Mean	0.8	1.0	1.2	1.1	1.6	0.9	1.8	0.3	1.7	1.2	1.8	1.3	1.3	0.5	4.0	0.3	1.5	1.3	1.6	1.6	1.0	0.8	3.0	0.2

[a]Very bright $H\alpha$ northwest group. [b]Very bright $H\alpha$ north central group. [c]Large active group 15° north of center of disk. [d]Very bright K_2 south central group. [e]Average-sized group at center of disk. [f]Moderately active group 12° north. [g]Sudden commencement at $16^h\ 24^m$ G. M. T.

Mount Wilson Observatory, Pasadena, California

SETH B. NICHOLSON
ELIZABETH E. STERNBERG

ORDRE DU JOUR PRÉLIMINAIRE DE LA RÉUNION DE LA COMMISSION INTERNATIONALE DE MAGNÉTISME ET D'ÉLECTRICITÉ ATMOSPHÉRIQUE À INNSBRUCK DU 21 AU 23 SEPTEMBRE 1931

Sur la demande du Président j'ai l'honneur de convoquer les membres de la Commission à une réunion qui aura lieu à Innsbruck du 21 au 23 septembre 1931. Le Bureau de la Commission mettra les points suivants à l'ordre du jour:

(I) Rapport du Président

(II) Election de nouveaux membres

(III) La publication du caractère magnétique

(IV) Relations avec l'Association de Magnétisme et d'Electricité Terrestres de l'Union Géodésique et Géophysique Internationale

(V) Année Polaire
- (a) Le réseau de stations
  - (1) de magnétisme terrestre
  - (2) d'électricité atmosphérique
  - (3) de courants telluriques
  - (4) d'aurore
  - (5) de radioélectricité
- (b) L'exécution du travail
  - (1) les préparatifs
  - (2) les observations
  - (3) le traitement des observations aux stations mêmes pendant l'Année Polaire
  - (4) la désirabilité d'une centralisation pendant l'Année Polaire des résultats obtenus
- (c) Publication des résultats
  - (1) la publication des observations
  - (2) la coopération internationale pour traiter les phénomènes de grande étendue

(VI) Adoption définitive des résolutions

Suivant l'article V, §5 du Règlement de l'Organisation Météorologique Internationale: "les personnes qui veulent proposer une question à la délibération d'une Conférence, du Comité ou d'une Commission devront préalablement demander aux Présidents intéressés que cette question soit mise à l'ordre du jour et envoyer, au plus tard deux mois avant la réunion, un court rapport sur cette question au Secrétariat, qui en distribuera des exemplaires aux membres de la Conférence qui en expriment le désir, aux membres du Comité ou de la Commission intéressée."

Je vous serais obligé, en conséquence, d'établir et de m'adresser bientôt vos propositions relativement aux questions à délibérer pendant la Conférence et le titre des communications scientifiques que vous voudrez faire à la Commission pour les mettre à l'ordre du jour.

Copenhague, le 2 mai 1931

D. LA COUR, *Secretaire de la Commission*

PRINCIPAL MAGNETIC STORMS

Sitka Magnetic Observatory

January to March, 1931[1]

(Latitude 57° 03′.0 N.; longitude, 135° 20′.1 or 9h 01m.3 W. of Gr.)

Greenwich mean time		Range		
Beginning	Ending	Decl'n	Hor. int.	Ver. int.
1931 *h m*	*d h m*		γ	γ
Jan. 16........ 6 ..	18 11 ..	62.9	486	302
Feb. 24....... 4 15	25 03 ..	90.8	966	632*

*Curve went off the paper in one direction.

The magnetic activity for this quarter was exceptionally low, the sum of the magnetic characters for the quarter being 23. The present observer has been at Sitka since 1918, and since that time there have been only two quarters when the magnetic activity was less. In the first quarter of 1921 the magnetic activity or the sum of the magnetic characters was 21 and in the third quarter of 1923 the sum was 23. The quarters of greatest activity were the second quarter of 1930 with a sum of 79, the first quarter of 1926 with a total of 70, and the third quarter of 1930 with a total of 68. The years of highest activities were 1930 with a total of 252, and 1918 with a total of 216. The years of lowest activity were 1923 with a total of 115, and 1921 with a total of 131.

The storm of January 16 to 18 was very small, with no particularly interesting or unusual features.

The storm of February 24 to 25 had a rather definite point of beginning; was quite active for a short period around 8^h and between 11^h and 13^h, and was also unusual in that it had a sudden ending, which was followed by normal values with no fluctuations.

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

Franklin P. Ulrich, *Observer-in-Charge*

Cheltenham Magnetic Observatory

January to March, 1931[1]

(Latitude 38° 44′.0 N.; longitude 76° 50′.5 or 5h 07m.4 W. of Gr.)

There were no magnetic storms recorded during the first quarter of 1931.

Geo. Hartnell, *Observer-in-Charge*

HUANCAYO MAGNETIC OBSERVATORY
JANUARY TO MARCH, 1931

(Latitude 12° 02′.7 S.; longitude 75° 20′.4 or 5ʰ 01ᵐ W. of Gr.)

February 13, 1931—There was a short magnetic disturbance on February 13, beginning at 8ʰ 58ᵐ (Greenwich mean time), with a rise of 28γ in five minutes in the horizontal-intensity trace. The disturbance was characterized by several sharp peaks and bays in horizontal intensity and by marked variations in the declination and vertical intensity. There was no sign of the subnormal horizontal-intensity values that usually mark magnetic storms at this observatory, either during the storm or thereafter. The storm ended February 13 at about 22ʰ. The ranges were 6′.0, 140γ, and 36γ in declination, horizontal intensity and vertical intensity, respectively.

PAUL G. LEDIG, *Observer-in-Charge*

WATHEROO MAGNETIC OBSERVATORY
SEPTEMBER, 1930 TO MARCH, 1931

(Latitude 30° 19′.1 S.; longitude, 115° 52′.6 or 7ʰ 43ᵐ.5 E. of Gr.)

Greenwich mean time					Range		
Beginning		Ending			Decl'n	Hor. int.	Ver. int.
1930	*h m*	*d*	*h*	*m*	′	γ	γ
Sep. 18	8 50	19	19	..	14	244	136
Nov. 13	19 28	15	16	..	17	105	66
Dec. 3	1 08	4	16	..	25	176	184
1931							
Feb. 24	4 14	25	03	..	11	99	100

November 13-15, 1930—This moderate storm began with a sharp sudden commencement, there being an increase of thirty γ in horizontal intensity. There were irregular but small fluctuations until the end of the storm.

December 3-4, 1930—The sudden commencement of this storm was marked by an increase in horizontal intensity so rapid over the first half-minute that no record was made by the spot. The total increase in horizontal intensity in the first three minutes was 22γ. On the other hand the vertical intensity decreased 7 γ and the declination changed 2′ easterly in the first minute, followed in the next two minutes by an increase in vertical intensity of 23 γ and a westerly change of 6′ in declination. The storm was of moderate intensity with long-period fluctuations.

February 24-25, 1931—This mild storm commenced suddenly with small decreases in all elements. There was a further slight disturbance from 17ʰ February 25 to 3ʰ February 26.

W. C. PARKINSON, *Observer-in-Charge*

REVIEWS AND ABSTRACTS

(See also page 110)

Angenheister, G.: *Geophysik.* II Teil. *Physik des festen Erdkörpers und des Meeres.* Unter der Redaktion von G. Angenheister bearbeitet von A. Defant, F. Hopfner, K. Jung, G. Kirsch, F. Kossmat, G. Krumbach, O. Meisser, H. Schmehl, G. Tammann, E. Tams. Wien-Harms, Handbuch der Experimentalphysik, Band 25, II. Teil. Leipzig, Akademische Verlagsgesellschaft m. b. H., 1931 (xiii + 823 mit 313 Abbildungen und 3 Tafeln.) Preis M. 74, gebunden M. 76.

The present volume is the second of the three parts which constitute Band 25 (Geophysics) of Wien-Harms monumental Handbuch der Experimentalphysik. The first part, which was published in 1928, was devoted to atmospheric phenomena and a general essay on the Earth's magnetic field. The third part, which appeared in 1930, contained a description of the various methods of applied geophysics. The present (second) part deals with the physics of the solid part of the Earth and of the oceans. Thus the large number of subjects usually included in the comprehensive term of geophysics are well covered by the three divisions of Band 25.

The second part here under consideration falls into two main divisions: (1) The physics of the solid Earth, and (2) the physics of the oceans.

In the first chapter, G. Tammann describes the changes in chemical composition which take place in the Earth. The following section, by G. Kirsch, is devoted to the radioactivity of the Earth. The development follows the two principal lines of interest to geophysicists, namely, the recognized principle that radioactive substances play an important part as sources of energy (heat) in maintaining the thermal balance in our planet, and the possibility, by reason of their independence of other physical conditions, of utilizing these substances in the measurement of geological time.

Introducing a section on the form of the Earth's surface with a consideration of the materials which compose the Earth's crust, F. Kossmat takes up in succession the present terrestrial relief, the factors which tend to bring about changes in the form of the Earth's surface, history of the Earth's surface, etc. He concludes with a detailed discussion of the chief theories regarding crustal movements and the problem of the ocean-bottoms.

Over 200 pages of the volume are devoted to the figure of the Earth, to gravity, and to the distribution of the mass of the Earth. Astronomical and geodetic methods of determining the size and figure of the Earth and gravity-determination, particularly by absolute and relative pendulum-measurements, are set forth in detail by H. Schmehl. Supplementing these expositions, K. Jung discusses regional and local gravity-anomalies, isostasy, tidal oscillations, horizontal pendulum, rigidity and mean density of the Earth, constant of gravitation, pressure in the Earth's interior.

The section on earthquakes is contributed by E. Tams. He dwells particularly on their frequency and intensity, geographic distribution, causes, etc. The theory of earthquakes with description of seismometric instruments and registrations, as well as information regarding the structure of the Earth's interior as derived from seismic data, are contributed by O. Meisser and G. Krumbach.

The portion of the volume devoted to physical oceanography is written by A. Defant and F. Hopfner. The former turns his attention to the extent and depths of the oceans, the physical and chemical properties of sea-water, the temperature and salinity of sea-water, statics and kinematics of the oceans, dynamics of ocean-currents, and oceanic circulation. F. Hopfner is responsible for the final section on the subject of tides, discussing especially their nature, theory, and observation.

The volume may be recommended as an up-to-date compendium of our present knowledge of the subjects treated. An adequate subject- and author-index is provided, facilitating reference to any desired topic.

H. D. Harradon

National Research Council: *Physics of the Earth—III: Meteorology.* Prepared under the auspices of the Subsidiary Committee on Meteorology. Washington, D. C., Bull. Nation. Res. Council, No. 79, 1931 (xi + 289 with 101 figs.). 24 cm. Price, $3.00; cloth, $3.50.

In accordance with the plan of the Division of Physical Sciences of the National Research Council, in coöperation with the Council's Division of Geology and Geography and the American Geophysical Union, to present in a series of bulletins systematic treatises on geophysical subjects, this book on meteorology has recently been offered to the public. It was prepared by a Subsidiary Committee on Meteorology of nine meteorologists under the chairmanship of Herbert H. Kimball. Each chapter is written by a man who is admittedly an authority on the branch of meteorology which he discusses. Herbert H. Kimball has written the introduction, Development of the science of meteorology. Chapter I, The atmosphere: origin and composition is by William J. Humphreys; Chapter II, Meteorological data and meteorological changes, by Alfred J. Henry; Chapter III, Solar radiation and its rôle, by Herbert H. Kimball; Chapter IV, The meteorology of the free atmosphere, by Willis R. Gregg, L. T. Samuels, and Welby R. Stevens; Chapter V, Dynamic meteorology, by Hurd C. Willett; Chapter VI, Physical basis of weather forecasting, by R. H. Weightman. To each chapter is appended an ample and well-selected bibliography.

The book presents to the reader, presumably a scientist, an easily understood, well-organized, and authoritative discussion of the status and outstanding problems of present-day meteorology.

Katharine B. Clarke

Pjaskousky, D. W., F. G. Newsky, M. P. Dobrochotowa, et W. A. Usfensky: *Magnitnaia i gravimetricheskaia s'emka oblasti Moskovskoi anomalii tiazesti.* (Données des observations gravimétriques et magnétiques du rayon de l'anomalie de la pesanteur à Moscou.) Moscou, Institut des Recherches Géophysiques, Bull. Geophys. No. 31. Travaux de l'Observatoire Géophysique à Koutchino, 1929 (140 avec cartes). 26 cm.

The first and larger part of this publication contains the results of gravity-determinations made in the vicinity of Moscow during the years 1924 and 1925.

The latter part, consisting of about 40 pages, contains the results of the magnetic observations which were made contemporaneously with the execution of the gravimetric survey. The practice was followed of selecting two magnetic stations lying at a rather short distance from each other, corresponding, in general, to each gravity-station. The observations were made by F. G. Newsky and M. P. Dobrochotowa, both connected with the Observatory of Kutchino near Moscow. Detailed descriptions of the various points where magnetic determinations were made (31 in number) are given. The results themselves are found in tables reduced to the epoch 1925.0 on the basis of data from the Observatory of Kutchino. Isomagnetic charts of the Moscow region, based on the above-mentioned results, have been constructed and are given at the end of the pamphlet.

The instruments used in the magnetic survey were as follows: Magnetic theodolite (Kew pattern) No. 168; magnetic theodolite (Cooke) No. 19; Dover dip circles Nos. 209-210; Hildebrand theodolite No. 4160 (small model); Nardin chronometer No. 649. The constants of theodolites Nos. 19 and 168 were determined by comparison with the magnetometer at the Slutzk (Pavlovsk) Observatory, the results of the comparisons being given in a table.

A study of the results of the survey of the Moscow region makes possible the construction of magnetic charts showing the presence of an anomaly the central point of which lies to the southwest of Moscow. Here the greatest departures from the normal values of the magnetic elements of the region surveyed are found.

An inspection of the charts discloses a certain correlation between the anomaly of magnetism and the anomaly of gravity both as regards the extent and the width of the anomalous strip and this correlation is indicated by the character of the distribution of the isomagnetic lines for all the elements.

H. D. Harradon

NOTES

(See also pages 98 and 132)

14. *Magnetic work in Switzerland*—We note with interest a communication in the Archives des Sciences Physiques et Naturelles of Geneva, indicating the progress of the magnetic survey of Switzerland, which is being carried on under the auspices of the Central Meteorological Institute of Zurich, with the support of the Federal Commission of Meteorology and the Helvetic Society of Natural Sciences. A preliminary survey having stations about 40 km apart furnished data for an approximate delineation of the isomagnetic lines. A new study of the detailed distribution of the magnetic elements has now been begun on the basis of a denser net (stations about 20 km apart). At the majority of the stations the usual elements (declination, inclination, and horizontal intensity) have been determined, but at some points only the declination was measured. In general, magnetic observations have been made at stations of the topographical survey, thus avoiding the necessity of observing on the Sun for determining the astronomical meridians. The instruments for the work were supplied by the Potsdam Magnetic Observatory and the Institut de Physique du Globe of the University of Paris. For obtaining data for use in reducing the results, an observatory has been equipped with photographically recording variometers at Regensberg, sufficiently distant from Zurich to be free from electric car-line disturbances.

As was to be expected from the geographical peculiarities of the country, the magnetic distribution is far from simple. For example, a very pronounced anomaly was found in southern Ticino, where also gravity-anomalies exist. Other anomalies are found in Valais, where they may be due to the presence of iron in the underground, and to the north of Lake Geneva, between the Préalpes and the Jura Mountains. It is believed that others will also be found in the central plateau.

15. *New Geophysical Observatory near Ashkabad*—At the meeting of the Hydrometeorological Committee of Turkmenistan, on January 20, 1931, the most southerly geophysical observatory of the Union of Socialistic Soviet Republics was founded. The observatory building is to be erected at a distance of about 10 km from Ashkabad (latitude = 37° 55′ north, longitude = 58° 23′ east of Greenwich), and it is expected that three sections, meteorological, aerological, and actinometrical, will be put into operation during the present year. On January 1, 1932, magnetic, electrometeorological, and seismological sections will be inaugurated. As it is desired to build up a reference-library, literature on pertinent geophysical subjects is solicited from other organizations engaged in similar work.

16. *Meteorological Experiment Station of the Deutsche Seewarte*—The Meteorological Experiment Station of the Deutsche Seewarte, which heretofore has been housed in barracks in Hamburg-Grossborstel, has moved into a new building at the Hamburg-Fuhlsbüttel airport. The Experiment Station was founded by W. Koeppen as a kite-station, and was for some time under the direction of Alfred Wegener. The new building contains laboratories for testing instruments and for scientific investigations, a workshop, and a small reference-library. The offices of the Meteorological Institute of the Hamburg University are also in this building. On the nearby flying field is located the "Wetterflugstelle Hamburg bei der Deutschen Seewarte" (Hamburg Aerological Station of the Deutsche Seewarte), which undertakes daily ascents up to 5 to 6 km. The aerological observatory of the Hamburg airport belonging to the Deutsche Seewarte is also in the immediate vicinity. The Experiment Station and the Institute are under the direction of the Professor of Meteorology at the Hamburg University, Dr. Albert Wigand.

17. *Lund Observatory Circular*—We have received the first two members of the Lund Observatory Circular, the first dated March 31, 1931. In these circulars it is proposed to publish short communications of the results reached by members of the staff and by other scientists connected with the Observatory, the longer papers appearing in the regular series of the Observatory publications. These concise communications, in English, French, or German, will be chiefly of an astronomical character, but since meteorological and seismological work forms part of the activities of the Observatory, occasional notes referring to these branches will be included. The circulars will be issued at irregular intervals as occasion demands, their number being restricted for the present to six per year containing in all about 96 pages.

18. *Summer courses in geophysical prospecting*—The Department of Geophysics of the Colorado School of Mines is offering this year a short course in geophysical prospecting. The course will be essentially a general résumé of the four major courses in torsion-balance, seismic, magnetic, and electrical prospecting. One week of lectures will be devoted to each of these subjects and the items covered for each method include a discussion of the fundamental principles, physical properties of rocks, description and theory of instruments and methods, theory of subsurface-effects, practice of interpretation and a description of results obtained on known geologic conditions. The week-ends will be devoted to laboratory- or field-work to enable students to obtain an

idea of the practical application of the methods. The Department's equipment and the school library of 24,000 bound volumes will be at the disposal of the students during the summer months.

The course will be given from July 27 to August 21. The work will be conducted personally by Dr. C. A. Heiland, and one assistant. The fee will be $50 and the expenses for the week-end field-trips will be borne by the students. Although there are no special entrance requirements, the nature of the instruction makes necessary a good working knowledge of physics, geology, and mathematics. Information may be obtained from Dr. C. A. Heiland, Department of Geophysics, Colorado School of Mines, Golden, Colorado.

19. *Fifth Pacific Science Congress*—The Fifth Pacific Science Congress will be held in Victoria and Vancouver, British Columbia, Canada, May 23 to June 4, 1932. The Sectional Committee on Meteorology and Terrestrial Magnetism is under the chairmanship of John Patterson, director of the Meteorological Service, Toronto. Papers intended for presentation at the Congress should be sent to the General Secretary as soon as possible (before December 31, 1931), to facilitate the work of printing the papers for distribution at the Congress. Both during the Congress and after the conclusion of the technical program excursions will be made to places of interest.

20. *Terrestrial magnetism and atmospheric electricty in Chile*—We are glad to announce on the basis of information received from the Chief of the Meteorological Office at Santiago de Chile, that it is planned to establish in the course of the present year a Section of Terrestrial Magnetism and Atmospheric Electricity under the auspices of the Meteorological Office. The projected Section is to be equipped with good instruments and will be ready to function at the beginning of next year, thus assuring the collaboration of Chile in the work of the International Polar Year 1932-1933.

21. *Measurement of the magnetic susceptibility of rocks*—In response to a request from the Geological Survey of Great Britain, the National Physical Laboratory has taken up the question of measuring the magnetic susceptibility of rock-specimens. After a survey of apparatus and methods available, it was decided to construct a magnetic balance similar to that described by Professor E. Wilson (Proc. R. Soc., A, 96, 429-455, 1920), which has the advantage of being simple and rapid in use. Although very high precision is not obtainable with this balance, the experience gained with the simpler form of apparatus should make possible the development of a better design in case it is desired later to increase the accuracy of the measurements. The instrument is now complete and suitable specimens have been cut from the first lot of rock-samples submitted.

22. *Personalia*—Professor *Raoul Gautier*, honorary director of the Observatory of Geneva, president of the Swiss National Committee of Geodesy and Geophysics, and vice-president of the International Association of Geodesy, died April 19, 1931, at his home in Geneva, aged 76 years.

Professor *Luigi Palazzo*, Director of the Ufficio Centrale di Meteorologia e Geofisica of Rome, observed his seventieth birthday on January 18, 1931.

Professor *Alfred Wegener*, leader of the German Scientific Expedition 1930-1931 for studying the meteorology, geology, and glaciology of Greenland, who lost his life in the course of the Expedition, has been succeeded by the brother Professor *Kurt Wegener*.

Dr. *E. Gaviola*, formerly physicist in the Department of Terrestrial Magnetism, has been appointed professor of physical chemistry and director of the Physical-Chemical Laboratory of the Faculdad de Ciencias Exactas, Fisicas y Naturales, of the University of Buenos Aires.

At the recent meetings of the American Geophysical Union, *J. A. Fleming* was reelected General Secretary of the Union, and *C. H. Swick* was elected Secretary of the Section of Geodesy, each for a period of three years beginning July 1, 1931.

Dr. *Joaquim de Sampaio Ferraz* has been compelled, because of his continued illness, to retire February 10, 1931, from the active directorship of the Brazilian Meteorological Institute, which he has successfully conducted since its establishment by him in 1921. In this capacity he has been succeeded by *Raul Pires Xavier*. Dr. Sampaio Ferraz's retirement will not, however, prevent his coöperation in the direction of the Institute and the pursuit of his private meteorological studies.

Raymond G. Ambrose, Magnetic Observer of the Coast and Geodetic Survey, is about to undertake the revision of all the magnetic stations in North Carolina which have been reported missing or in bad condition. This work is in coöperation with the Department of Conservation and Development of the State of North Carolina.

Lieutenants *T. T. Tsai* and *C. Y. Ho*, of the Chinese Navy, have been engaged in studying the methods of magnetic observations of the Coast and Geodetic Survey and the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, in anticipation of undertaking magnetic work in China.

Floyd M. Soule, observer and electrical expert, Department of Terrestrial Magnetism of the Carnegie Institution of Washington, sailed on April 30, from New York for Bergen, Norway, where he will join the Wilkins-Ellsworth Tran-Arctic Submarine Expedition.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Alexanian, M. C. Règles pratiques pour l'emploi du magnétomètre dans les prospections géophysiques. Paris, Ann. Office Nation. Combustibles Liquides, v. 5, No. 4, 1930 (677-702).

Barret, W. M. A method for determining magnetic susceptibility of core samples. New York, N. Y., Amer. Inst. Min. Metall. Eng., Tech. Pub. No. 394, 1931, 20 pp.

Bauer, Louis A., and J. A. Fleming. Annual report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, 1929-30. Repr. Washington, D. C., Carnegie Inst., Year Book No. 29, 1930 (249-322). 25-1/2 cm.

Brückmann, W. Le levé magnétique de la Suisse. Arch. Sci. Phys., Genève, Pér. 5, v. 12, 1930 (392-393).

Buehler, H. A. Geophysical prospecting. Rolla, Mo., Biennial Rep. State Geologist, App. 3, 1931 (146-151 with 5 maps). 22 cm. [Brief report regarding the electric-resistivity and magnetic-survey work by the Missouri Bureau of Geology and Mines during field seasons 1929 and 1930.]

Chapman, S., and A. T. Price. The electric and magnetic state of the interior of the Earth, as inferred from terrestrial magnetic variations. London, Phil. Trans. R. Soc., A, v. 229, 1930 (427-460).

Chapman, S., and J. M. Stagg. On the variability of the quiet-day diurnal variation. Part II. London, Proc. R. Soc. A, v. 130, 1931 (668-697). [Summary: The discussion of the range of the daily magnetic variation, on very quiet days, previously considered for the two stations Eskdalemuir and Greenwich, is extended to four more stations, Ebro, San Fernando, Batavia, and Mauritius. It is found that the ranges vary from day to day in an irregular way, and that there is a definite correlation between the changes in different elements and at different stations—the correlation being less, the more distant the stations. It is found that the very quiet days often occur in sequences of two or more, and that there is a tendency for abnormalities of range to persist for two or more days.]

Chevrier, J. Reconnaissance magnétique en Syrie. Paris, C.-R. Acad. sci., T. 192, No. 16, 1931 (977-978). [Values of declination, inclination, and horizontal intensity are given for 19 stations.]

Copenhagen, Det Danske Meteorologiske Institut. Magnetisk aarbog, 1ste del: Danmark (undtagen Grönland)—Annuaire magnétique, lère partie: le Danemark (excepté le Groenland). 1929. Köbenhavn, G. E. C. Gad, 1930 (30). 32 cm.

Eblé, L., et J. Itié. Valeurs des éléments magnétiques à la Station du Val-Joyeux (Seine-et-Oise) au 1er janvier 1931. Paris, C. R. Acad. sci., T. 192, No. 11, 1931 (690-691).

Egypt, Physical Department. Meteorological report for the year 1924. Cairo, Ministry Pub. Works, Physical Dept., 1930 (xiii+168). 32 cm. [Contains values of the magnetic elements at Helwan Observatory for 1924.]

Eve, A. S. A magnetic method of estimating the height of some buried magnetic bodies. New York, N. Y., Amer. Inst. Min. Metall. Eng., Tech. Pub. No. 408, 1931, 8 pp.

Fleming, J. A. Proceedings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union held in Stockholm, Sweden, August 15-23, 1930. Abstract: J. Wash. Acad. Sci., v. 21, No. 5, 1931 (90-92).

Fleming, J. A., and H. W. Fisk. On the distribution of permanent repeat-stations. Zs. Geophysik, Braunschweig, Jahrg. 7, Heft 1/2, 1931 (74-80).

Fonseca, J. A. da, e J. S. Vaz. Valores dos elementos do magnetismo terrestre da Provincia de Moçambique. Lourenço Marques, Imprensa Nacional, 1925 (40 com 2 cartas). 31 cm. [Publication of the Observatorio Campos Rodrigues. Contains summary of magnetic observations in Mozambique with sketch showing lines of equal magnetic declination in the Bay of Louenço Marques 1924-1925.]

Hongkong, Royal Observatory. Monthly meteorological bulletin, December, 1930. Containing detailed results of observations made at the Royal Observatory, Hongkong, and the daily weather reports from various stations in the Far East, together with mean monthly and annual values of the principal meteorological elements at Hongkong, typhoon tracks, and results of magnetic observations made in the year 1930. Prepared under the direction of T. F. Claxton, Director. Hongkong, Noronha and Co., 1931 (ca. 60 with map.).

Koutchino, Observatoire de. Travaux de l'Observatoire Géophysique de Koutchino près Moscou, 1928. Bulletin de magnétisme terrestre. Moscou, Bull. Géophys., Inst. Res. Géophys., No. 35, 1930 (ca. 144 pp.). 30 cm.

McFarland, W. N. Results of observations made at the United States Coast and Geodetic Survey Magnetic Observatory at Vieques, P. R. in 1923 and 1924. Washington, D. C., Dept. Comm., U. S. Coast Geod. Surv., Ser. No. 498, 1931 (94 with 10 figs.). 27 cm.

Results of observations made at the United States Coast and Geodetic Survey Magnetic Observatory near Tucson, Arizona, in 1923 and 1924. Washington, D. C., Dept. Comm., U. S. Coast Geod. Surv., Ser. No. 499, 1931 (101 with 10 figs.). 27 cm.

Malkin, N. Relation entre le potentiel et ses gradients sur une surface sphérique et son application à la théorie du magnétisme terrestre. Leningrad, Bull. Acad. sci., No. 8, 1930 (739-755). [Texte russe.]

Relation entre les gradients du potentiel newtonien sur un plan et son application à l'étude des anomalies gravifiques et magnétiques. Leningrad, Bull. Acad. sci., No. 8, 1930 (757-771). [Texte russe.]

Mathias, E., Ch. Maurain, et L. Eblé. Nouveau réseau magnétique de la France au 1er janvier 1924. Deuxième mémoire. Distribution générale des éléments magnétiques en France. Extr. Ann. Inst. Physique du Globe, Univ. Paris, T. 8, 1930 (37-62 avec une carte). 31 cm.

Maurer, H. Deviationsänderung durch starke Sonnenbestrahlung. Ann. Hydrogr., Berlin, Jahrg. 58, Heft 12, 1930 (440-442).

Mauritius, Royal Alfred Observatory. Results of magnetical and meteorological observations for the months of February to August, 1930 (new series, v. 16, pts. 2-8). Port Louis, Govt. Press, 1930 (20-143). 34 cm.

Meldau, H. Bemerkungen zu einer vorgeschlagenen Aenderung der Deviationsformel. Ann. Hydrogr., Berlin, Jahrg. 58, Heft 12, 1930 (442).

Mercanton, P. L. Inversion de l'inclinaison magnétique aux âges géologiques. Nouvelles observations. Paris, C.-R. Acad. sci., T. 192, No. 16, 1931 (978-980)

Mission Rohan-Chabot. Mission Rohan-Chabot, sous les auspices du Ministère de l'Instruction Publique et de la Société de Géographie. Tome 2. Opérations relatives à l'établissement d'une carte des régions parcourues. Magnetisme—Météorologie. Paris, Imprimerie Nationale, 1930 (xxxiv+171 avec 1 carte dans une pochette). 28 cm. [La partie de l'ouvrage se rapportant au magnétisme terrestre comprend les titres suivants: 1. Mesures magnétiques déjà faites en Angola. 2. Instruments. 3. Stations. 4. Observations et calculs (déclinaison, inclinaison, et composante horizontale). 5. Résultats (mesure des trois éléments magnétiques; étude de la variation diurne de la déclinaison.) 6. Description des stations et des mesures. Les stations sont au nombre de 47, dont 44 en Angola et 3 en Rhodesia.]

Mögel, H. Ueber die Beziehungen zwischen Störungen des Kurzwellenempfangs und den erdmagnetischen Störungen. Zs. Geophysik, Braunschweig, Jahrg. 7, Heft 3/4, 1931 (207-212). [Dieser Vortrag sollte einmal der Geophysik aus der Praxis heraus zeigen, mit welchen Mitteln es der Kurzwellentechnik heute möglich ist, Zustandsänderungen der Kennelly-Heaviside-Schicht durch das Experiment systematisch zu erforschen. Ferner wurde angestrebt, nach abschliessender

Mitteilung der bisher in der Transradio-Empfangsanlage Geltow bei Potsdam gesammelten Beobachtungsergebnisse eine systematische Zusammenarbeit mit dem Observatorium Potsdam zu erreichen.]

MOUNT WILSON OBSERVATORY. Summary of Mount Wilson magnetic observations of sunspots for November, 1930, to February, 1931. Pub. Astr. Soc. Pacific, San Francisco, Cal., v. 43, 1931 (79-82; 160-163).

NEWSKY, F. G., M. P. DOBROCHOTOWA, UND W. A. USPENSKY. Magnetische Beobachtungen, die im Gebiete der Moskauer Anomalie der Schwerkraft in Jahren 1924-25 angestellt wurden. Moscow, Inst. Recherches Geophys., Bull. Geophys. No. 31, 1929 (105-140 mit 4 Kart.). [Russian text with German summary.]

NIPPOLDT, A. Ergebnisse der erdmagnetischen Beobachtungen in Seddin im Jahre 1929. Met. Zs., Braunschweig, Bd. 47, Heft 12, 1930 (487-488).

ONO, S. Disturbance in the magnetic observations caused by the electric works. Geophys. Mag., Tokyo, v. 3, No. 3, 1930 (229–289).

PARIS, INSTITUT DE PHYSIQUE DU GLOBE. Annales de l'Institut de Physique du Globe de l'Université de Paris et du Bureau Central de Magnétisme Terrestre. Publiées par les soins de Ch. Maurain. Tome VIII. Paris, Les Presses Universitaires de France, 1930 (iv+144 avec figs. et 1 carte). 31 cm. [A signaler: L. Eblé—Observations magnétiques faites au Val-Joyeux pendant l'année 1928; E. Tabesse—Observations magnétiques faites à l'Observatoire de Nantes pendant l'année 1928; E. Mathias, Ch. Maurain, et L. Eblé—Distribution générale des éléments magnétiques en France. Formules représentatives. Définition numérique des anomalies; Ch. Jacquet et H. Bellocq—Mesures magnétiques dans les Basses-Pyrénées, la Corse, la Charente, la Gironde et les Landes; V. A. Kostitzin—Sur l'agitation magnétique et ses relations avec l'activité solaire; G. Grenet—Sur le magnétisme des roches; D. Daude—Contribution à l'étude des particules en suspension dans l'atmosphère; Lieutenant de Vaisseau Laurent—Observations magnétiques dans les possessions françaises du Pacifique; Principales perturbations magnétiques en 1928 (graphiques obtenus aux enregistreurs du Val-Joyeux).]

POLLAK, L. W. Die Perioden und das Periodogramm der internationalen erdmagnetischen Charakterzahlen. Prag. Cech. Statistik, Bd. 64, Prager Geophys. Studien, Heft 3, 1930 (107 mit Fig.). 31 cm. [Das vorliegende Heft behandelt die Perioden und das Periodogramm der internationalen erdmagnetischen Charakterzahlen, somit ein Material, das durch internationale Zusammenarbeit der erdmagnetischen Observatorien der ganzen Erde gewonnen wurde, und ein Problem, das, dank des noch ungeklärten Zusammenhanges zwischen Sonnentätigkeit und magnetischen Störungen, auch theoretisches Interesse beanspruchen darf. Inhaltsverzeichnis: 1. Die zeitlichen Variationen des Erdmagnetismus und die erdmagnetischen Störungen. Die verschiedenen Masse der erdmagnetischen Aktivität. 2. Die bisherigen Bearbeitungen der internationalen Charakterzahlen. Die mehrtägigen Perioden der magnetischen Stürme. 3. Material. 4. Methode. 5. Ergebnisse. Literaturnachweise und Erläuterungen.]

PUZICHA, K. Die magnetischen Eigenschaften der Eruptivgesteine. Zs. prak. Geol., Halle (Saale), Bd. 38, 1930, No. 11 (161-172); No. 12 (184-189).

RIO DE JANIERO, OBSERVATORIO NACIONAL. Annuario publicado pelo Observatorio Nacional do Rio de Janeiro para o anno de 1931. Anno XLVII. Rio de Janeiro, Imprensa Nacional, 1931 (xv+426 com mappa). 18 cm. [Contains tables of magnetic declination at various points in Brazil reduced to epoch 1931.0 and an isogonic map of Brazil for September 1922.]

SCHMIDT, AD. Ueber die sterntägige Schwankung des Erdmagnetismus. Zs. Geophysik, Braunschweig, Jahrg. 7, Heft 1/2, 1931 (134).

Zur Frage der hypothetischen sterntägigen Variation. Zs. Geophysik, Braunschweig, Jahrg. 7, Heft 3/4, 1931 (198).

SMITH, F. E. El magnetismo terrestre. Ibérica, Barcelona, Año 18, 1931, Núm. 864 (95-96), Núm. 865 (110-112); Núm. 866 (126-128). [Spanish translation of presidential address before the Section of Physical and Mathematical Sciences of the British Association, Bristol, September 8, 1930.]

STAGG, J. M. Atmospheric pressure and the state of the Earth's magnetism. Nature, London, v. 127, Mar. 14, 1931 (402).

STENZ, E., AND H. ORKISZ. O pracach magnetycznych Instytutu Geofizycznego Uniw. J. K. we Lwowie w latach 1928-1929. (Report of the magnetic investigations of the Geophysical Institute of Lwów University during the years 1928-1929.) Lwów, Inst. Geophys. Univ., Comm. No. 60, 1930 (429-443).

STONYHURST COLLEGE OBSERVATORY. Results of geophysical and solar observations, 1930. With report and notes of the Director, Rev. E. D. O'Connor. Blackburn, Thomas Briggs, Ltd., 1931 (xxv+49). 18 cm.

TACUBAYA, OBSERVATORIO ASTRONOMICO NACIONAL. Anuario del Observatorio Astronomico Nacional de Tacubaya para el año de 1931. Formado bajo la dirección del Ing. Joaquin Gallo. Tacubaya, Universidad Nacional de Mexico, 1930 (295). 19 cm. [Contains the mean values of the magnetic declination and horizontal and vertical components, for the year 1929 and the first six months of 1930, as derived from the magnetograms of the Magnetic Observatory of Teoloyucan.]

TENANI, M. Risultati delle osservazioni magnetiche eseguite durante la permanenza della R. N. "Città di Milano" allo Spitsbergen. (Giugno-Luglio, 1928.) Padova, Tipografia del Seminario, 1930 (10 con 2 fig.). [Paper presented at the meeting of the Section of Terrestrial Magnetism and Electricity, International Geodetic and Geopgysical Union, Stockholm, 1930.]

Stato attuale della cartografia magnetica. Pisa, Bol. Com. Naz. Ital. Geod. Geof., Ser. 2, Anno 1, No. 1, 1931 (2-6). [Si ricorda brevemente la parte avuta in passato da studiosi Italiani nelle recerche di magnetismo terrestre: in particolare, si esamina l'origine e si discute il valore delle carte magnetiche più recenti e si mettono in rilievo le difficoltà attuali pel proseguimento in Italia delle ricerche magnetiche e, in particolare, per l'aggiornamento della cartografia.]

TIFLIS, GEOPHYSIKALISCHES OBSERVATORIUM GEORGIENS. Magnetische Beobachtungen in Karssani 1927. Tiflis, 1930 (83). 25 cm. [Text in Georgian, Russian, and German.]

TOKYO, CENTRAL METEOROLOGICAL OBSERVATORY. Annual report of the Kakioka Magnetic Observatory for the year 1928. Tokyo, 1931 (44 with 12 pls.). 30 cm. [Contains besides the values of the magnetic elements an account of the magnetic variability observed at the Kakioka Magnetic Observatory, Japan, for 1928, pp. 41-44.]

WEINBERG, K. Beitrag zur Methodologie der Rekonstruktion der Deklinationsverteilung für ältere Zeiten. Zs. Geophysik, Braunschweig, Jahrg. 7, Heft 3/4, 1931 (192-193).

B—Terrestrial and Cosmical Electricity

ALIVERTI, G., E M. C. MONTÙ. Su inversioni del campo elettrico terrestre a cielo sereno e una loro possible spiegazione. Repr. Nuovo Cimento, Bologna, Anno 8, No. 1, 1931 (7). [Summary: There is described the anomalous course of the potential gradient at Col d'Olen on Monte Rosa during a day which judging from the atmospheric conditions, might be expected to be quite normal. A plausible explanation of the phenomenon is given by showing how the formation of space-charges would be possible if only at a certain distance from the station there were clouds or simply layers of stationary fog. In such layers are accumulated charges of opposite sign with respect to the upper and lower edges under the action of the Earth's electric field, resulting from the different conductivity of the layer with reference to the surrounding air. Wind of differing intensity and different direction finally separate the two portions of the cloud or fog having different space-charges.]

APPLETON, E. V. A method of measuring upper atmospheric ionisation. Nature, London, v. 127, Feb. 7, 1931 (197).

ARCHENHOLD, F. S., UND G. ARCHENHOLD. Elektrizität auf der Erde und im Kosmos. Weltall, Berlin, Jahrg. 30, Heft 2, 1930 (17-21).

BANERJI, S. K. The electric field of overhead thunder-clouds. London, Q. J. R. Met. Soc., v. 56, No. 236, 1930 (305-334).

BARTELS, J. Polarlicht, Theorie und Beobachtung. Naturw., Berlin, Jahrg. 19, Heft 8, 1931 (190-191). [A digest of recent work, both theoretical and observational, on the aurora.]

BAYARD-DUCLAUX, MME F. La conductibilité électrique de l'air à Paris. Paris, C.-R. Acad. sci., T. 192, No. 13, 1931 (810-812).

BELLUIGI, A. Dall'utilizzazione del rapporto delle distribuzioni dei campi potenziale e elettro-magnetico alle determinazione delle caratteristiche di profondità e potenza dei giacimenti nei rilievi geoelettrici. Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 1, Heft 3, 1931 (241-254).

BLAIN-BRICOURT, H. L'aurore boréale du 17 octobre 1930. Paris, Bul. soc. astr. France., 45e année, 1931 (80-81). [Notes by other observers are appended to the article. One by Prof. Carl Störmer states that the display was magnificent in Norway, particularly at Kongsberg where 26 good photographs of the aurora were obtained.]

BOUTARIC, A. Les aurores polaires. L'observation et la photographie des aurores. Nature, Paris, 57e année, No. 2855, 1931 (337-341 avec 10 figs.).

BOWER, S. M. Summer thunder-storms. Met. Mag., London, v. 66, No. 782, 1931 (36). [Proposal of commencing a census of thunder-storms occurring in the six summer months on April 1, 1931. The requisite details of observation are stated. It is expected that this census will extend over the summers of 1931 to 1936, in order that sufficient data may be available for comparison with the winter material already obtained.]

BRÜCHE, E. Störmers Polarlichttheorie in Experimenten. Erster Teil. Ebene Bahnen. Zs. Astroph., Berlin, Bd. 2, Heft 1, 1931 (30-69).

Polarlichtexperimente und Elektronenstrahlkompass. Forsch. u. Fortschr., Berlin, Jahrg. 7, Nr. 5, 1931 (70-71).

CAMERON, G. H. The mysterious cosmic rays. How scientists have endeavored to solve this mysterious energy. North American Almanac, Chicago, Ill., 1931 (161-163).

CHAPMAN, S. The audibility and lowermost altitude of the Aurora Polaris. Nature, London, v. 127, Mar. 7, 1931 (341-342).

CLAY, J. Ultra radiation (penetrating-radiation). III. Annual variation and variation with the geographical latitude. Amsterdam, Proc. Akad. Wet., v. 33, 1930 (711-718).

CORLIN, A. Messungen der Höhenstrahlungsintensität zwischen 55° und 70° nördlicher geographischer Breite. Vorläufige Mitteilung. Repr. Ark. Matem. Uppsala, Bd. 22 B, No. 2, 1930 (6 pp.).

Ergebnisse der Ultrastrahlungsmessungen in Nord-Schweden. Physik. Zs., Leipzig, Jahrg. 31, Heft 23, 1930 (1065-1071).

An indication of a correlation between cosmic ultraradiation and terrestrial magnetism. Lund, Obs. Cir., No. 1, Mar. 31, 1931 (3-12). Additional note, *ibidem*, No. 2 (34).

Observations of a low altitude aurora and simultaneous phenomena. Nature, London, v. 127, April 11, 1931 (553-554). [The aurora described was observed at Abisko, Sweden, on Nov. 16, 1929.]

DAS, A. K. Origin of cosmic penetrating-radiation. Naturw., Berlin, Jahrg. 19, Heft 14, 1931 (305-306).

EDGE, A. B. B. Geoelectrical prospecting by A. C. bridge methods. Nature, London, v. 127, Jan. 3, 1931 (37-39). Supplementary note: *ibidem*, Mar. 21, 1931 (443).

ELIAS, G. J. Reflection of electromagnetic waves at ionized media with variable conductivity and dielectric constant. New York, N. Y., Proc. Inst. Radio Eng., v. 19, No. 5, 1931 (891-907).

FERRARO, V. C. A. A note on the possible emission of electric currents from the Sun. London, Mon. Not. R. Astr. Soc., v. 91, No. 1, 1930 (174-184).

On recombination in ionized streams of corpuscles from the Sun. London, Mon. Not. R. Astr. Soc., v. 91, No. 1, 1930 (184-187).

FICKER, H. VON. Ueber die Entstehung lokaler Wärmegewitter. 1. Mitteilung. Berlin, SitzBer. Akad. Wiss., 1931 (28-39).

FOUST, C. M. Instruments for lightning measurements. Gen. Elec. Rev., Schenectady, N. Y., v. 34, No. 4, 1931 (235-246). [Latest developments and applications of surge-voltage recorders, cathode-ray oscillographs, lightning-stroke recorders, surge indicators, lightning-severity meter.]

Gates, R. R. The audibility and lowermost altitude of the Aurora Polaris. Nature, London, v. 127, Mar. 28, 1931 (486). [Description of a remarkable auroral display observed at Fort Smith on Slave River in the Canadian Northwest (latitude 60° north) on the evening of August 10, 1928. It is stated that colored streamers moved slowly across the sky, frequently almost horizontally, each one gradually slackening until it came to rest, and its movement being clearly accompanied by a low hissing or swishing sound like that of gas escaping from a tap under pressure, the sound dying down with the slackening speed of the streamer. The height of the aurora was estimated at not greater than a fraction of a mile.]

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NOTICE

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 36 SEPTEMBER, 1931 No. 3

THE INFLUENCE OF HYDROSTATIC PRESSURE ON THE CRITICAL TEMPERATURE OF MAGNETIZATION FOR IRON AND OTHER MATERIALS

BY L. H. ADAMS AND J. W. GREEN

Abstract—This cooperative investigation by L. H. Adams and J. W. Green, of the Geophysical Laboratory and Department of Terrestrial Magnetism, respectively, both of the Carnegie Institution of Washington, was undertaken principally because of its bearing on the Earth's magnetic field and its relation to the problem of the central iron-core. The object was to determine whether or not the temperature at which iron and other ferromagnetic substances pass from the magnetic to the non-magnetic state is affected by an increase of pressure.

The specimens of the materials investigated were made up as the core of a miniature transformer or induction-unit, and placed in an electrically heated pressure-bomb. A six-volt alternating-current was supplied to the primary of the transformer and the output from the secondary was amplified, rectified, and carried to a direct-reading galvanometer. The temperature of the inversion-point, indicated by the galvanometer-reading dropping to zero, was measured by means of platinum-platinrhodium thermocouples.

Five ferromagnetic metals were used. Determinations were made at pressures up to 2,000 atmospheres for iron and magnetite, 2,200 atmospheres for nickel, 2,600 atmospheres for nickel-steel, and, in the case of meteoric iron, 3,600 atmospheres. The results indicate that pressure has practically no effect on the inversion-point, although the possibility of a slight decrease is not excluded, as there was a slight tendency toward depression, especially in the case of nickel-steel and meteoric iron.

On the whole, it seems a fair inference that the pressure-coefficient of the magnetic inversion-point remains zero or negative even at the high pressures in the Earth's interior, and that consequently the permeability of the nickel-iron core of the Earth is not significantly higher than that of ordinary rocks.

This investigation was undertaken principally because of its bearing on the Earth's magnetic field and its relation to the problem of the central iron-core. It is now generally accepted that within the Earth is a metallic core which consists mainly of iron with a few per cent of nickel, and has a diameter of about 6,000 kilometers or a little less than one-half the diameter of the whole Earth. So large an amount of iron, if it were in the usual ferro-magnetic state, would have a profound influence on the magnetic field observed at the surface and would be one of the major factors entering into any theory of the Earth's magnetic field. When it is remembered, however, that iron loses its magnetic quality at a temperature less than 800° (called the magnetic inversion-temperature or Curie-point) and that in the interior of the Earth the temperature, while difficult to estimate satisfactorily, is certainly of the order of some thousands of degrees, it would seem at first thought that iron in the interior would have no effect on the magnetism of the Earth.

On the other hand, the high pressure within the Earth might possibly offset the effect of high temperature. The pressure at various depths below the surface may be estimated quite satisfactorily; at the top of the iron core it is 1,800,000 atmospheres, and at the center, 3,200,000 atmospheres. These pressures are of such magnitudes that it is evident that even a small specific effect of pressure on the critical temperature of magnetization might suffice to maintain the iron core in the ferro-magnetic state. It becomes of importance, therefore, to make any possible measurements on the change of the magnetic inversion-point with pressure.

In beginning this investigation the authors were not unmindful of the difficulties which would arise—difficulties not only of experimentation, but more especially of interpretation and application. It was noted, however, that of the three possibilities concerning the pressure-coefficient of the inversion-temperature, namely, that this temperature should rise, remain constant, or fall with increasing pressure, only the first would fail to lead to definite conclusions concerning the interior, since if the inversion-point were lowered by pressure or unaffected by it there would be good reason for believing that the interior temperature is above the critical temperature of magnetization and that the iron-core is non-magnetic.

Thus the proposed investigation, which was of interest from the purely physical standpoint, seemed likely also to yield valuable results to geophysics. Accordingly, an extensive series of measurements was carried out with five ferro-magnetic materials—iron, nickel, magnetite, nickel-steel, and meteoric iron.

Description of materials used—The iron was from three different sources. Very pure electrolytic iron was obtained from the United States Bureau of Standards, and Swedish iron and Armco iron from commercial sources. Since no significant difference was detected in the behavior of these three samples under pressure, the results have been lumped together under "iron."

The nickel was from a piece of commercial rolled sheet. It was not analyzed, but was believed to be very pure.

The magnetite was from a large crystal of natural magnetite which was furnished by the United States National Museum.

The nickel-steel was from a small bar furnished by the United States Bureau of Standards. It contained 35 per cent nickel, a small amount of carbon, and a trace of chromium.

The meteoric iron was taken from a piece of the Canyon Diablo meteorite, which was furnished us by the United States National Museum. The composition, according to J. E. Whitfield,[1] is as follows: Fe (metallic), 89.17 per cent; $FeCl_2$, 0.10 per cent; iron oxides, 2.52 per cent; Ni, 7.34 per cent; Co, 0.51 per cent; Cu, 0.02 per cent; P, 0.26 per cent; S, 0.01 per cent; C (combined), 0.11 per cent; C (graphitic), 0.03 per cent; Si, trace. There are also present minute amounts of other elements.

Apparatus and method—The specimens were subjected to the combined action of high pressure and high temperature in an apparatus which had been used at the Geophysical Laboratory in previous investigations.[2] The electrically heated pressure-container or bomb is shown

[1] Merrill, Am. J. Sci., **35**, 513 (1913).

[2] Smyth and Adams, J. Am. Chem. Soc., **45**, 1167-1184 (1923).

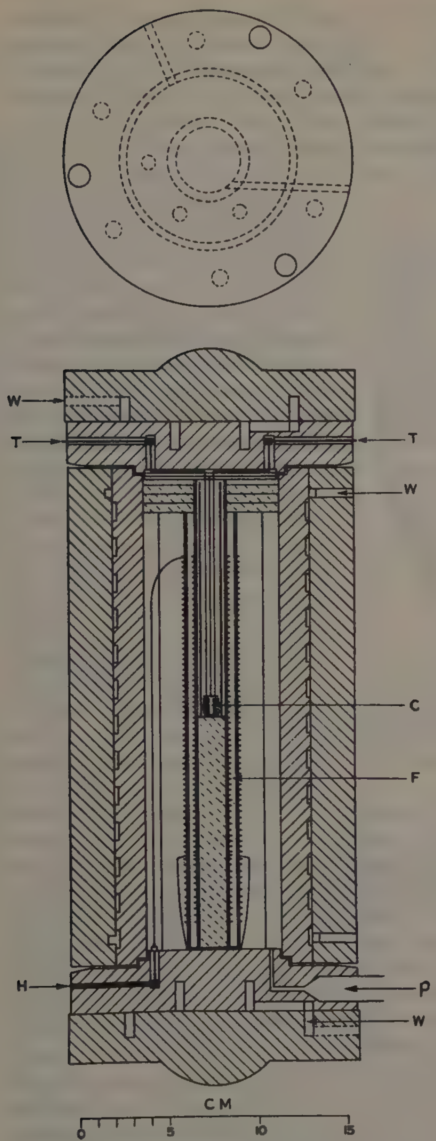


FIG. 1—Cross-section and plan of electrically heated pressure-apparatus (The ends are held on by means of a hydraulic press; current is supplied to the platinum furnace-winding F through insulated connections H; the walls and also the ends are cooled by water that is forced into channels at W; carbon dioxide is pumped into the bomb at P; the induction-unit is shown at C connected to three of the five wires which pass through insulated connections T at the top.)

diagrammatically in Figure 1. Essentially it consists of a cylinder of vanadium-steel made in two parts, with the outer cylinder shrunk on the inner one, which has an internal diameter of 75 mm. A spiral groove between the two parts allows the circulation of cooling-water. The bomb is closed on either end by lids which also are made in two parts for ease in constructing the water-cooling passages. Through the upper lid pass five electrically insulated leads, three of which are for the thermo-couples used to measure the temperature within the bomb, the other two providing the means for an additional electrical circuit. Through the lower lid pass the leads (of phosphor-bronze wire 3 mm in diameter) for the electric furnace.

The lids are held on by means of an ordinary hydraulic press, which is adjusted to produce a thrust of 30 to 50 tons greater than the thrust exerted on the lids from within the bomb, the joints being made pressure-tight by thin copper gaskets.

The medium for transmitting pressure was the ordinary commercial grade of liquid carbon-dioxide, and was pumped into the bomb through a pipe-connection in the lower lid.

Temperature in the bomb was measured with platinum-platinrhodium thermo-couples and a potentiometer, the sensitivity being such that one division on the scale was equivalent to 0°.1. Pressure was measured on a Bourdon gauge to within 20 bars (metric atmospheres), which was ample sensitivity in view of the expected magnitude of the effect under investigation.

The method for determining when a specimen exposed to pressure within the bomb had become non-magnetic consisted in measuring the inductive effect in the secondary of a miniature trans-

former the core of which was made of the material under investigation. The construction is shown in Figure 2. Round bars 10 mm long and 2 mm in diameter formed the sides. They were turned with a shoulder on each end and were fitted snugly into holes drilled in the end-pieces, which were flat plates 10 mm long, 4 mm wide, and 1 mm thick.

In the case of magnetite some difficulty was experienced in making the round bars. Satisfactory results, however, were obtained by using a transformer the side-rods of which were iron and the end-plates magnetite. Since the magnetic inversion-point of magnetite is much lower than that of iron, the magnetic circuit, when the transformer-coil was heated, would be broken when the inversion-temperature of the magnetite had been attained, and the magnetic behavior would therefore be practically the same as if the core were made entirely of magnetite.

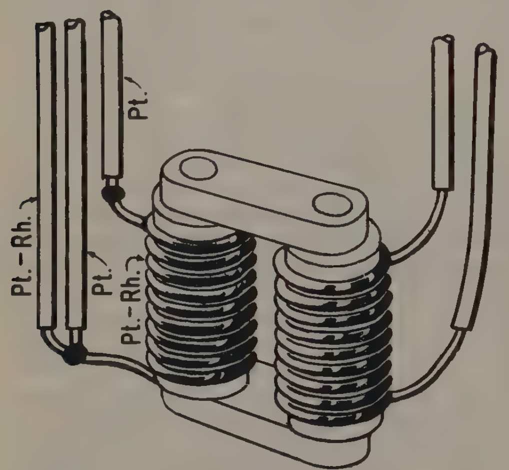


Fig. 2—Diagram of the induction-unit (height, 1 cm)—primary and secondary coils, insulated by silica-glass, are wound on a frame made of the material under investigation

The primary and secondary coils of the transformer, or induction-unit, were wound on thin-walled silica-glass tubing and were slipped over the round side-bars. The primary winding consisted of 9 turns of 0.4 mm bare platinum wire wound with 0.3 mm space between the turns. The secondary winding was made to serve the purpose also of two thermo-couples for measuring the temperature at the top and bottom of the sample. This was accomplished as follows: The secondary winding was of 10 per cent platinrhodium 0.4 mm in diameter, with the same number of turns as in the primary, and at the top was fused to a wire of pure platinum 0.4 mm in diameter, thus forming a thermocouple-junction for measuring the temperature of the upper end of the induction-unit. At the lower end the platinrhodium wire was extended beyond the winding to form the second terminal of the coil, and there was fused to it near the lower end of the coil another wire of pure platinum, forming a second thermocouple-junction. The three terminal-wires were connected to wires leading through the top end of the bomb, thence through cold-junctions insulated by glass tubes and dipping in ice, and thence to a switching arrangement for connecting to the device for measuring the inductive effect or to the potentiometer on which could be measured the temperature of either the top or the bottom of the induction-unit or the difference between them.

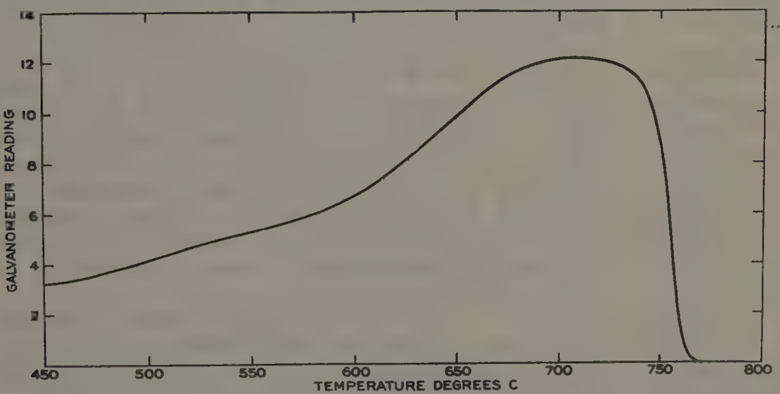
The measurement of the inductive effect was accomplished as follows: A 6-volt, 60-cycle alternating-current was supplied to the primary of the small induction-unit. The output from the secondary was amplified by a three-stage electron-tube amplifier, after which it was carried

to a rectifying tube and thence to a portable microammeter, used as a direct-reading galvanometer.

This method gave ample sensitivity with all the material investigated, and, furthermore, allowed readings to be taken rapidly and with ease and certainty. So long as the specimen was ferro-magnetic the galvanometer showed a steady deflection, the magnitude of which depended on the permeability of the specimen. At or above the inversion-temperature the deflection was zero.

The current used in the primary coil was small, usually about 0.3 ampere. The field strength thus generated may be easily calculated, being about 1.6 gauss, or approximately eight times the mean horizontal intensity of the Earth's field.

The experimental procedure was as follows: The induction-unit having been placed in the silica-glass tube and packed with crushed silica-glass, and the five terminals having been joined by fusion to the appropriate wires on the under side of the top lid, the lid was carefully lowered on the bomb and about 50 tons applied with the hydraulic press. Liquid carbon-dioxide was then pumped into the bomb until the desired



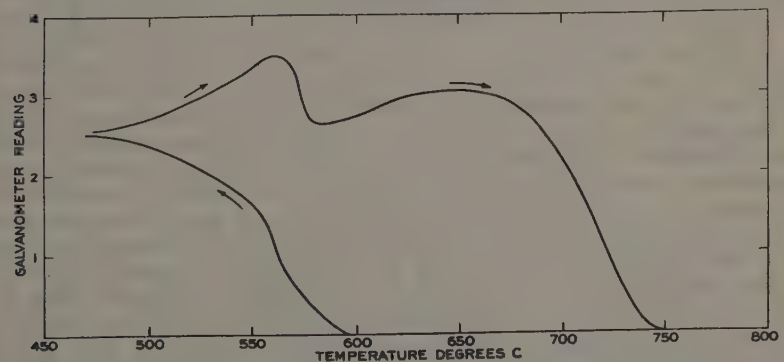


FIG. 3—Typical heating-curve for iron—the magnetic induction increases with rising temperature and then drops sharply at the Curie-point; the cooling-curve is practically coincident with the heating-curve for iron and also for the other materials except meteoric iron

FIG. 4—Typical heating- and cooling-curves for meteoric iron—the ferromagnetism is lost on heating at a considerably higher temperature than that at which it is regained on cooling

pressure was attained, while at the same time the force exerted by the press was increased. Ordinarily it was not necessary to raise the pressure to the required amount entirely by pumping, since the increase of pressure during the heating would supply a considerable part of the pressure. Thus, for example, it was sufficient to start with a pressure of 1,200 atmospheres in order to have 2,000 atmospheres when the temperature had reached 260°, and with a pressure of only 600 atmospheres to have 2,000 atmospheres at 800°.

During the first part of the heating the rate was fairly rapid, but at a temperature about 200° below the inversion-point the rate was lowered to 10° or 15° per minute and the series of readings was started. There were recorded primarily (1) the inductive effect as indicated by the galvanometer, (2) the temperature of one end of the induction-unit, (3) the difference in temperature of the two ends, and (4) the pressure; and, secondarily, the current through the primary of the induction-unit, and the current through the furnace-winding. Initially, readings were taken at intervals of about 10°, but as the temperature of the inversion was approached the heating rate was decreased to about 1° per minute and readings were taken at intervals of 1° or less. When the critical temperature had been passed, as shown by the inductive effect having fallen to zero, the heating-current was reduced so that the temperature fell slowly, and a cooling-curve was determined in the same manner as the heating-curve. The pressure was then lowered somewhat by allowing carbon dioxide to escape through a valve, and another heating- and cooling-curve obtained at the lower pressure. In this way observations at several pressures were made with one filling of the bomb.

Experimental results—A typical heating-curve for iron is shown in Figure 3, in which the temperature is plotted as abscissa and the electromagnetic effect as ordinate. This effect is given in arbitrary units, being merely the reading of the galvanometer.

From Figure 3 it may be seen that the inductive effect at first rises with increasing temperature. This apparently represents the normal behavior of the permeability of ferro-magnetic materials in weak fields. The rise continues to a point just below the inversion-point where the curve begins to drop sharply, trailing off a trifle just before it falls to zero.

The same type of heating-curve was obtained for nickel, magnetite, and nickel-steel as for iron. Moreover, for these four materials the cooling-curve was practically coincident with the heating-curve. For the meteoric iron, on the other hand, a different type of curve was obtained, as shown in Figure 4. Here, with increasing temperature, the permeability rises to a maximum at 550°, falls rapidly, then begins to rise again, and finally falls rather slowly to the transformation-point, 745°. Upon being cooled the material does not begin to regain its ferromagnetism until a temperature of 600° is reached. Meteoric iron is a complicated mixture of iron, nickel, and other substances, and it is evident from the heating- and cooling-curves that there are present at least two separate phases of different magnetic properties. The meteoric iron is essentially a nickel-steel with about 7 per cent nickel. It is of interest to note that nickel-steels with low nickel-content are known to regain their magnetism at a temperature considerably lower than that at which they lose it upon being heated.

Although many interesting and unexpected problems were presented in the course of this work, the object of the present investigation was to

determine the magnetic inversion-temperatures under various pressures, and hence it was only the end-points of the curves that were of primary interest. The curves did not fall very sharply to zero, yet it was possible in most cases to determine, with an error of less than 1°, the temperature at which the induction-effect became zero. The transformation-points are plotted in Figure 5. Altogether about 600 separate runs were made, each including a heating- and cooling-curve. When more than

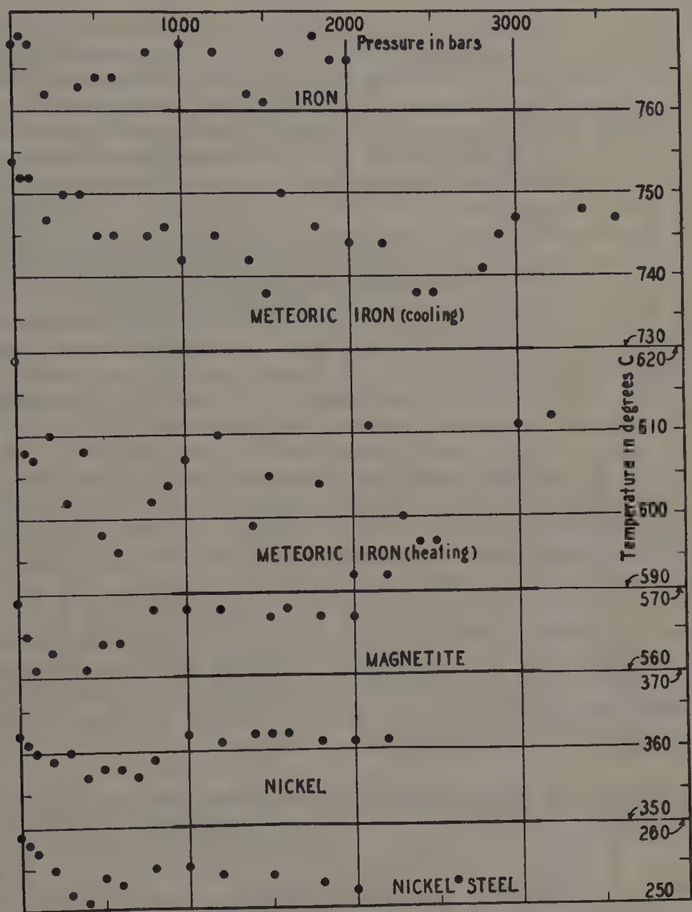


FIG. 5—The temperatures of the magnetic inversion (Curie-points) for the five ferromagnetic materials investigated as a function of pressure showing the pressure-coefficient to be practically zero for all of the materials

one determination was made at a given pressure the results have been averaged to give a single point. The heating- and cooling-points also were lumped together except for meteoric iron.

Discussion—From the inversion-temperatures at various pressures as plotted in Figure 5 it may be seen, considering the open scale of temperature, that there is no very pronounced trend of the transforma-

tion-points with increasing pressure. The results are not as regular as might have been expected, especially for the meteoric iron, both heating and cooling, but this material is complex in composition and apparently the inversion-temperature depends to some extent on the previous history of the sample. Nickel and nickel-steel gave the most regular results. This is probably because at the low temperature of the transformations in these two materials the temperature was much more uniform within the bomb.

Pressure seems to have little or no effect on the magnetic inversion-points for the five ferro-magnetic materials under investigation. If there is any trend at all, it is in the nature of a slight decrease in temperature with increasing pressure. It is reasonable to suppose that this same situation holds at very much higher pressures, and at even the extreme pressures deep within the Earth. Therefore, since the temperature in the interior cannot be less than several thousand degrees, and since the effect of pressure is *not* to raise the magnetic inversion-point, it can be stated with almost complete assurance that the metallic core of the Earth does not have the familiar magnetic quality of iron or nickel-iron alloys, and that the iron-core is without influence on the Earth's magnetic field. There is, of course, a possibility that pressures of more than a million atmospheres may produce unexpected effects analogous to the well-known phenomenon of supra-conductivity, which is encountered at extremely low temperatures. It has been suggested that such pressures may cause a complete breakdown of the whole atomic structure, with profound and unpredictable consequences. Such considerations, it is true, introduce an element of uncertainty into conclusions of any kind regarding matter under extreme temperatures and pressures, but whatever may be the situation in the interior of stars, no evidence, either direct or indirect, has yet been obtained which makes it appear probable that anything very revolutionary will take place under the conditions of temperature and pressure in the interior of a planet like the Earth. On the whole it seems a fair inference that the pressure-coefficient of the magnetic inversion-point remains zero or negative even at very high pressures in the Earth's interior, and that consequently the permeability of the iron-core of the Earth is not significantly higher than that of ordinary rocks.

Table 1—*Miscellaneous data concerning the five ferro-magnetic materials investigated*

Material	Composition	Curie-point			Heat of inversion
		Previous values		Present values	
		Range	Weighted mean		
		°	°	°	cal/g
Iron	Fe	740–810	768	768	5.5
Nickel	Ni	340–380	360	362	1.2
Magnetite	Fe_3O_4	530–590	575	569	...
Nickel-steel (35%)	Fe-Ni	261		259	...
Meteoric iron (Canyon Diablo)	Essentially Fe with 8% Ni	...		754 (heating) 619 (cooling)	..

Summary—Measurements have been made on the effect of pressure on the magnetic inversion-temperature (Curie-point) for five ferromagnetic materials, iron, nickel, magnetite, nickel-steel (35 per cent nickel), and meteoric iron from the Canyon Diablo meteorite. Pressures as high as 3,600 bars (metric atmospheres) were used.

Although the results show minor inconsistencies, they demonstrate that the effect of pressure on the inversion-point is practically *nil*, but the possibility of a slight decrease in temperature, with increasing pressure, is not excluded.

If, as seems reasonable, this tendency still holds qualitatively at the very high pressure in the interior of the Earth, it must be concluded that the nickel-iron core, which has a diameter about one-half and a volume about one-ninth of the Earth's, is at a temperature far above that at which it could be magnetic. The nickel-iron core, therefore, in spite of its great volume, has no important influence on the Earth's magnetic field.

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NOTES

(See also pages 238 and 242)

23. *Aeroarctic trial polar flight*—Supplementing our note (*Terr. Mag.*, **36**, p. 132) we can now announce the successful conclusion of the first polar flight under the auspices of Aeroarctic (officially designated "Erste Arktische Studienfahrt der Aeroarctic") with the *Graf Zeppelin*. On this flight various geophysical observations were executed, the magnetic work being in charge of Dr. S. Ljungdahl, of Sweden, assisted by Lieut.-Commander E. H. Smith, of the United States Coast Guard, and Mr. Lincoln Ellsworth. The principal magnetic instrument used on this flight was the double-compass subsidized by the Carnegie Institution of Washington, from which previous tests have indicated that good results may be expected. Other instruments for magnetic determinations taken on the flight were a Thomson compass-rose, obtained by Dr. Ljungdahl from Stockholm, with fiber-suspension, for determining the declination by the projection of the Sun's shadow on the card (a system used by Prof. Haussmann on flights last year with good results), and a sensitive Schmidt field-balance mounted on gimbals for the determination of vertical intensity. During the flight the following points were visited: Leningrad, Archangel, Novaya Zemlya, Franz Joseph Land, and North Land. Unfavorable weather prevented stopping at Leningrad on the return trip. For the first time in the history of polar exploration, an airship was successfully landed on the surface of the water in the arctic. On July 27, the *Graf Zeppelin* made a landing in the water near the Russian ice-breaker *Malyguin* and unloaded more than 100 pounds of mail. During this time she rested on air-filled floats. On account of the menacing ice-floes all about, the mail-sacks were exchanged as quickly as possible with the *Malyguin*, and the airship proceeded on her way. Preliminary reports received to date indicate that considerable strips of coast-line were mapped and several new islands discovered.

The expedition left Berlin on July 25 and returned on July 30, the time required for the flight being thus six days. In the course of the 8,000-mile flight (Friedrichshafen, Leningrad, Archangel, Franz Josef Archipelago, Northern Land, Taymir, Novaya Zemlya, Archangel, Friedrichshafen) 92 determinations of magnetic horizontal-intensity were made with the double-compass, 75 of which were on the cruise from Archangel to the north and return to Archangel. Eight observations of magnetic declination were made with a Thomson compass-rose with fiber-suspension. No vertical-intensity measurements could be obtained because the Schmidt field-balance could not be used due to slipping of the magnet caused by vibrations of the airship. In reducing the observations the registrations of Seddin, Sloutsk, and Matochin Shar will be utilized.

24. *Wilkins-Ellsworth Trans-Arctic Submarine Expedition*—Since preparing the previous note (*Terr. Mag.*, **36**, p. 132), the submarine *Nautilus* left New London, Connecticut, June 2, 1931, for Provincetown, Massachusetts, from which port, after various tests had been made, she proceeded on her transatlantic voyage June 4, with the intention of calling at London, en route to Bergen, Norway, where members of the scientific staff were to join the expedition, and additional supplies and equipment were to be taken on board. Unfortunately, heavy seas were encountered and the submarine's engines were so disabled that it was necessary, June 15, to summon the United States battleship *Wyoming*, which towed her into Cobh (Queenstown, Ireland), arriving June 22. On June 26 she was taken to Plymouth, England, where new engine-cylinders were installed and other repairs made. She was not able to proceed on her way to Bergen until July 27, reaching that port August 1. Although much valuable time had been consumed by the necessary repairs, there still remained two or three weeks of arctic summer, which Sir Hubert Wilkins hoped to use for a restricted polar expedition this year. The *Nautilus* leaving Bergen August 5 arrived at Advent Bay, Spitzbergen, August 15, 1931, stopping en route at Tromsoe and Skjervoy, Norway. The party returned to Longyear City, Spitzbergen, September 8 having spent three weeks one day in an arctic cruise, which was limited in extent because of the lateness of the season.

A NEW THEORY OF MAGNETIC STORMS*

By S. Chapman and V. C. A. Ferraro

PART I—THE INITIAL PHASE (Continued)

6—*The phenomena accompanying the advance of a solar ionized stream into the Earth's field*

6.1—A stream of particles emitted nearly radially from an active area A on the Sun will have a curved form[23], on account of the Sun's rotation. The stream will lag slightly behind the solar radius through the emitting area A, though each particle of the stream will move almost rectilinearly, approximately along the solar radius through the position of A at the instant of emitting that particle. The rate at which the lateral surface of the stream will approach the Earth, overtaking it in its orbital motion, depends only on the Sun's known angular velocity; the point of intersection of the Earth's orbit with the lateral surface of the stream moves relative to the Earth with a velocity of about 400 km/sec, thus traversing a distance equal to one Earth-radius in about 18 seconds. If undisturbed by the Earth's field the stream would sweep across the Earth in about 35 seconds.

The advancing surface of the stream would take about 15 minutes to reach the Earth from a distance of 50 Earth-radii, where the Earth's magnetic intensity is only 0.3γ. After a further 15 minutes the forward surface would have passed through the more intense part of the field to the distance at which the intensity is once more only 0.3γ. From this time until 15 minutes before the *following* surface of the stream sweeps across the Earth, the whole of the region in which the magnetic field has an intensity exceeding 0.3γ is within the stream. If this period is assumed to be of the same order of duration as the active period of a magnetic storm, it is about one day. This would correspond to a diameter of cross-section of the stream, at the Earth's orbit, of about 5,000 Earth-radii.

If this be the order of magnitude of the diameter of the stream, then as viewed from the Earth the stream will subtend an angle of nearly 2π (the angle subtended at any point by an infinite plane) when the nearest point of the stream is at a distance of 50 radii from the Earth (assuming that at this distance the surface is undistorted by the field). Actually, at this distance, the angle subtended by the stream (which can for this purpose be treated as an infinite cylinder of diameter 5,000 Earth-radii) is about $\frac{7}{8}$ of 2π. The radius of curvature of the surface being fifty times the distance from the Earth, the surface will appear nearly plane as viewed from the Earth.

6.2 In the earlier stages of our work we made many attempts to find whether the charged surface-layer on the stream, due to the polarization by the magnetic field, could produce any appreciable magnetic effect near the Earth, either during the approach of the stream-boundary towards the Earth, or while the Earth is enveloped in the stream. One great difficulty in making these attempts was the essentially three-dimensional character of the problem; it seemed scarcely possible to seek the usual refuge of the applied mathematician in analytical distress, and attempt as an alternative to solve some sufficiently illustrative

*Continued from this Journal, **36**, 77-97 (1931). The following correction is to be noted on page 83 in the sixth line of the last paragraph of Section 1: For "in Figure 1" read "in Figure 5."

analogous problem in two dimensions; two-dimensionality seemed attainable only by omitting some essential feature of the phenomena. It was at this stage that, starting with the problem of §5, we were forced back to examine the simpler problems of §§2-4. Also other simple problems were attempted, and partly solved, concerning the state of streams of *small* section approaching or passing by the Earth. It is unnecessary to describe the details of these attempts; their result was to convince us that, as in the simple cases of §§2 and 3, the magnetic field, near the Earth, due to the moving charged layers, regarded as electric currents, was negligible.

6.3—We also endeavoured to find whether the charges *escaping* from the surface, under the influence of the external electric field of the charged layer, could provide sufficient current, in the Earth's neighbourhood, to produce an appreciable disturbance of the magnetic field; the surface-charge on the stream, when approaching the Earth, is negative, and the escaping particles are electrons. Our conclusion, after detailed examination, was that their terrestrial magnetic effect was negligible; when the stream is many Earth-radii distant from the Earth, the surface-density of charge, the external electric field, and the rate of escape of charge, are all very small; moreover the escaping electrons do not approach near the Earth, at least in the equatorial plane, though many of them may find their way along the Earth's lines of force towards the auroral zones.

The "escape" of particles from the surface, at this distance, is analogous to the very large lateral motion (§2.7) of the surface-layer of an infinite plane-slab stream in a very weak uniform field; in the terrestrial case, owing to the non-uniformity of the field outside the stream, and its great increase of intensity around the Earth, the motion of the charged layer of the stream will not be simply periodic and pulsatory the charges may pass quite beyond the reach of the electric field of the stream, and never return to it. But as the stream approaches the Earth, the "spiral radius" of the electrons in the charged layer will be progressively reduced; for example, at a distance of 50 Earth-radii, or 15 minutes travel of the surface, from the Earth, the spiral radius of the outermost electrons, at the point on the surface of the stream that is nearest to the Earth, will be only about 20 km, and in the equatorial plane the electrons will not "escape" from the surface further than this, but will oscillate to and from the surface over this distance. Those not in the equatorial plane can move farther away, and may escape towards the auroral zone along the Earth's lines of force. But since the increasing negative charge of the surface-layer, as it approaches the Earth, coincides with increasing attachment of the layer (by the influence of the Earth's magnetic field) to the surface, the equivalent current, and its magnetic field, will approximate more and more in order of magnitude (or upper limit) to those that can be estimated by analogy with §2.4; H will be altered at most by an amount of the order $(V^2/c^2)H'$, where H' is the intensity of the Earth's field at the layer; if $V=10^8$, this would be negligible even if the layer were in contact with the Earth. If $V=10^9$, $(V^2/c^2)H'$ would not then be negligible: but we shall show that, actually, the surface cannot approach within several Earth-radii before the field greatly distorts it, and induces other phenomena of much greater importance than the magnetic effect of the (undistorted) charged surface-layer. We therefore attribute no importance, for the theory of magnetic

storms, to the surface-charge on the boundary of the solar stream, *while this is approaching the Earth with little or no distortion.*

6.4—We believe our first real insight into the mode of production of magnetic storms was gained when we perceived that a further surface-effect would arise owing to the advance of the stream into the Earth's field—an effect not paralleled in the illustrative problems previously considered. The stream, as mentioned in the introduction (§1.6), is an electrical conductor, and the motion of the terrestrial magnet relative to this conductor will induce electric currents in it, tending to shield the interior of the stream from the changes in the field. These currents initially flow near the surface, and parallel to it; gradually they diffuse inwards, and the degree of magnetic shielding in the regions newly invaded by the currents is progressively reduced.

If the conductivity of the stream, and its rate of advance into the Earth's field, are sufficiently great, so that the stream is a nearly perfect conductor, the interior will be almost completely shielded from the Earth's field. The tubes of force occupying the region traversed by the field will be, as it were, pushed forward by the stream. This will increase the magnetic intensity around the Earth—an effect which is characteristic of the first phase of a magnetic storm.

6.5—This compression of the Earth's tubes of magnetic force into a smaller volume represents an increase in the magnetic energy of the field, gained at the expense of the kinetic energy of the stream, whose particles are retarded by the field. The retardation here mentioned is additional to, and greater than, the one previously discussed; that was due to the polarization of the stream by the field, and the lost kinetic energy was converted partly into electrostatic energy and partly into magnetic energy, though the change in the latter was very small; the whole body of the stream is subject to the retardation due to the polarization. The retardation of the stream due to the magnetic shielding of its interior is effected by electromagnetic forces acting on the induced currents flowing near the surface; the retarding force acts only on the part of the stream, near the surface, which conveys the electric currents, while the interior is unaffected. It is, of course, true that the shielding of the interior of the stream from the magnetic field removes the polarizing forces on the interior, and so eliminates the former type of retardation.

6.6—The retarding force per unit surface-area of this current-layer at any point is proportional to the tangential intensity (H_s) of the field, and to the current density (i) at the point; and i will be approximately proportional to the normal velocity (v_n) of the surface, and to H_s. Thus, in all, the retarding force will be approximately proportional to $v_n H_s^2$. In the equatorial plane $H_s = H$, the surface being there, by symmetry, perpendicular to this plane; since $H \propto 1/r^3$, where r denotes distance from the Earth's centre, the retarding force varies as v_n/r^6; this rapidly increases as the surface approaches the Earth, except in so far as the velocity of approach, v_n, is simultaneously reduced.

The stream will first be retarded, during its approach to the Earth, on the advancing side, nearest the Earth. As the stream continues to advance, the approaching particles near the surface on the sunward side of the Earth will be increasingly retarded, and the surface will become bent round the space occupied by the Earth's magnetic field. After the time when, if the field had been absent, the surface of the stream would

have swept past the Earth, the actual surface, on the forward side, will be entering into a weaker field, where it is less retarded; thus it will be able to advance, along the direction of motion of the particles, beyond the part of the surface immediately between the Sun and the Earth. A hollow space, of which the equatorial section is roughly parabolic in form, with its axis lying nearly along the line from the Sun to the Earth, and its vertex on this line (not far from the Earth on its sunward side), will thus be formed by distortion of the stream-surface. Successive

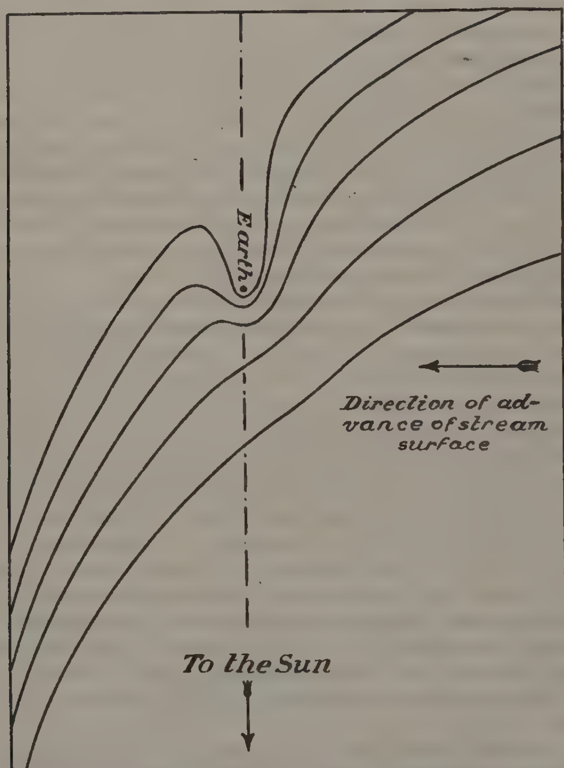


FIG. 2—Successive equatorial sections of the surface of advancing stream

stages in the formation of this hollow are shown in Figure 2 by sections in the equatorial plane.

6.7—In so far as the interior of the stream is shielded from the magnetic field, the ions and electrons there will move forward without deflection or retardation due to polarization. Those immediately behind the current-bearing surface-layer will therefore overtake this retarded layer, and increase its mass-density; they will then share in the transmission of the induced current, and in the consequent retardation; the effect of the increased density upon the electric conductivity is discussed in §8.

The rate of retardation of the surface is governed by the magnitude

of the retarding force, and the mass on which it acts. The latter constantly increases by the inpouring of particles from the interior into the current-bearing layer, and also by the gradual backward diffusion of the currents, and the consequent thickening of the layer. The retarding force (roughly proportional to v_n/r^6) tends to increase on account of the increased intensity of the field into which the surface advances; but the decreasing velocity of advance tends to reduce the force. The surface will continue to advance, at a decreasing rate; the actual rate of retardation, and the effect on the magnetic field, are matters for detailed calculation (§7). They depend essentially on the momentum of the stream per unit volume. This is probably sufficiently small (§1.6) for the velocity of the surface to be greatly reduced.

6.8—If there were no upper limit to the density of the streams which the Sun could emit, magnetic storms might be produced that would have characteristics markedly different from those that are observed; very dense streams would be only slightly retarded, and though they would produce an increase in the field near the Earth during their approach, this would be a fleeting phenomenon; the "hollow" would in their case be only a slight depression in the advancing surface, which would sweep up to and across the Earth; only the region in the shadow of the Earth would then be free from the stream.

On the other hand, there is a lower limit to the stream-density that suffices for the production of the phenomena described in this section (§6); the ions and electrons of a very rare stream would be separately deflected as if they were independent particles, and the stream could not be regarded as a conducting medium. In a very rare stream of ions and electrons the advance of the electrons would be stopped at a far greater distance from the Earth than that to which the ions could attain; in this case the excluded spaces inaccessible to the particles of either kind are those discussed in Störmer's auroral theory.

6.9—The analytical discussion of the distortion of the surface of the stream by the Earth's field, and the magnetic consequences, offer difficulties which we have not yet overcome or, indeed, seriously attacked as yet. Our course has been to consider simpler problems that seem to illustrate the main features of the actual case with sufficient closeness to enable us to draw numerical conclusions of at least the right order of magnitude.

We begin by considering the current-system in a *rigid* infinite plane conducting-sheet approaching the Earth. The bearing of the results in this case, upon the problem of the non-rigid conducting-stream, is then discussed. This is followed by a numerical calculation intended to illustrate the rate of advance of the *apex* of the hollow surface, as a function of the momentum-density of the stream. The increase of magnetic intensity within the hollow, and its rate of change, are estimated, and it is suggested that they can reasonably be identified with those that are observed in the first phase of a magnetic storm. The identification leads to numerical estimates of the momentum-density of the solar streams.

7—*The currents induced in a conductor moving in a magnetic field, and their magnetic effects*

7.1—We first consider the currents induced in an infinite *thin* plane conducting-sheet ($z=0$), by a magnetic system of any kind (on the side

$z>0$) advancing with constant velocity, $-w$, normal to the sheet. Maxwell[32] showed that the problem could be reduced to the determination of a single function, so long as the ethereal displacement-currents are negligible, which is the case if w/c is small. We denote the current (or stream) function for the sheet by Ψ, the magnetic potential of the inducing system by Ω, the magnetic potential due to the current-sheet, in the region on the same side as the inducing magnetic system, by Ω', and the specific resistance per unit area of the sheet by $2\pi w_0$; w_0 has the dimensions of a velocity. It is clear that Ω' will be an even function of z, the field of the current-system being symmetrical with respect to the sheet.

The equations of induction being linear, the effects of different systems are additive, and so it is sufficient to consider the simple case of a magnetic bipole, taken to be of moment M, at a point P ($z>0$). Let P' be the image-point of P with respect to the sheet, that is, the point on the same normal, at an equal distance from the sheet on the side $z<0$. Then the magnetic effect of the currents induced in the sheet is to reduce the field on the further side ($z<0$) in the ratio $w_0/(w+w_0)$, the same at every point, as if the sheet were absent and the doublet at P were of moment $Mw_0/(w+w_0)$. On the side $z<0$ an additional field, such as would be produced in that region, in the absence of the sheet, by a positive image-doublet of moment $Mw/(w+w_0)$ at P', is superposed on the field of the doublet M; this increases the magnetic energy of the field in this region, though the intensity is not changed everywhere in the same ratio, nor even everywhere increased.

These results are valid whatever the direction of the doublet. They are unaffected also if the sheet moves towards the doublet instead of *vice versa*, the relative motion being the determining factor (the rate of propagation of changes in the field is here regarded as infinite).

Any magnetic system can be built up by superposition of simple doublets. Hence the above discussion indicates that on the further side of the sheet the field of the system, when moving as a whole towards the sheet, at right-angles, is reduced in the ratio $w_0/(w+w_0)$. The change in the field on the same side as the system itself corresponds to the superposition of a field of the same character as the unaltered field of the system on the further side, but of only $w/(w+w_0)$ times the intensity.

7.2—The case of most interest for our problem is that in which the doublet is parallel to the sheet. If its axis is taken to be in the y-direction, its potential at (x, y, z), when P is at the point $(0, 0, c)$, is My/r^3, where

$$r^2=x^2+y^2+(z-c)^2 \tag{23}$$

The current-function Ψ is given by

$$\Psi=\frac{w}{w+w_0}\,\frac{My}{2\pi\; r_0^{\,3}} \tag{24}$$

where $r_0^{\,2}=x^2+y^2$. Thus the current-lines are the lines of intersection of the sheet with the equipotential surfaces of the field; they are shown in Figure 3. The current-system consists of two families of ovals, separated by the line $y=0$; their foci or limiting points Q are at $(0, \pm c/\sqrt{2}, 0)$, where the equipotential surfaces touch the sheet, that is, where

[32] J. C. Maxwell, Electricity and magnetism, 2d ed., Oxford, 1881, Ch. XII, § 657.

the magnetic lines of force of the doublet cross the sheet at right-angles. At any other point the current-components are

$$\frac{1}{2\pi}\frac{w}{w+w_0}(-H_y, H_x, 0) \tag{25}$$

where H_x, H_y, are the x, y components of the field of the doublet. In

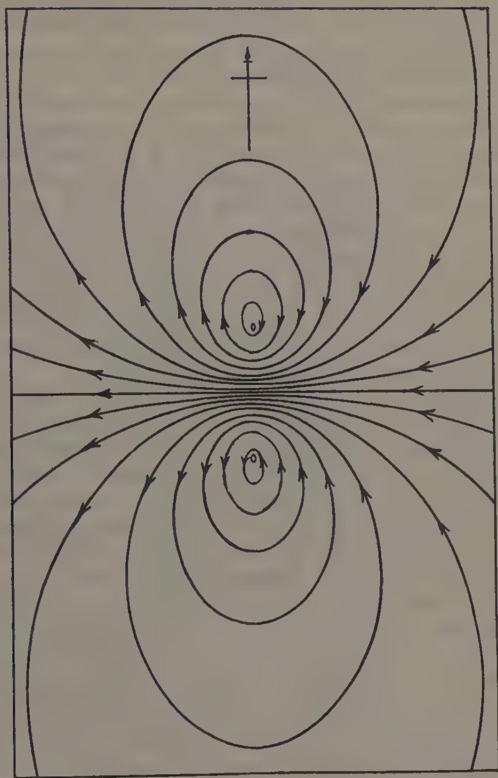


FIG. 3

the equatorial plane of the doublet, $y=0$, the current is along the x-direction, and of amount

$$\frac{1}{2\pi}\frac{w}{w+w_0}\frac{M}{(x^2+c^2)^{3/2}}. \tag{26}$$

If the sheet were a perfect conductor ($w_0=0$) the far side would be completely shielded from the field of the doublet, and the image-doublet which gives the additional field on the near side would have the full moment M.

7.3—The determination of the induced currents and magnetic effect is more difficult when the magnetic system moves *parallel* to the sheet. If the velocity u parallel to the sheet is *large* compared with w_0, the field of the current-sheet would almost annul the field on the far side, and on the near side would add to the field by a corresponding amount; for example, for a doublet M, by nearly the field of the full image-doublet

M; but in addition there is a small lagging field (on both sides) of order w_0/u times the field just described.

The problem of a magnetic system moving parallel to and between a *pair* of highly-conducting infinite thin parallel plane-sheets can be treated approximately by the method of images. It is easy to see that, provided the magnetic system is not too near either sheet, the magnetic field between them will on the whole be increased by about twice or thrice the amount which either sheet alone could produce.

7.4—If the conductor is not a thin plane-sheet, but a body (of specific resistance $2\pi w_0'$) extending throughout the whole space on the negative side of the plane boundary $z=0$, the induced currents will flow parallel[33] to the surface, their intensity decreasing with increasing depth from the surface. The currents would be unaffected if the body were divided into a series of thin contiguous sheets parallel to the surface; each sheet would be subject to a magnetic field similar in *character* to the one that would exist there if the sheets between it and the surface were removed, but reduced in *intensity* by the shielding effect of the currents in these sheets. The magnetic field would thus be progressively reduced inside the body; the ratio of reduction at not too great a depth d below the surface would be approximately the same as that due to a thin sheet of specific resistance $2\pi w_0'd$, placed somewhere between $z=0$ and $z=d$.

The field outside the conductor would no longer be modified by the addition merely of a field equivalent to that of a single image-magnet; but if the currents are concentrated in a layer of which the thickness is small compared with the distance from the actual magnet to the surface of the conductor, their external field is nearly equivalent to that of an image-doublet in a perfectly conducting *thin* plane-sheet.

7.5—When the boundary of the body is not plane, the determination of the induced currents and their magnetic field is more difficult. Larmor[34] showed in 1884 that in the case of a conducting sphere, or spherical shell of sufficient thickness, "no external magnetic disturbance whatever can induce currents which do not circulate in concentric shells." Substantially the same conclusion may be drawn whatever the form of the surface, if its curvature changes only gradually from point to point; the penetration of a conductor by a varying magnetic field will be reduced, and, if the conductivity be sufficient, will be confined to a thin surface-layer, flowing in this layer nearly parallel to the surface; the current-intensity will decrease to a low value in a stratum of thickness varying inversely as the specific resistance w_0' of the body. If the body is of small dimensions, the available total conductivity may be inadequate to shield the interior to any appreciable extent, but whether the interior is well shielded or not, the *external* field of the induced currents will be small, because the displacement of the tubes of force which would otherwise pass through the body affects only a correspondingly small region of the field.

In all cases of *complete* shielding of a magnetic field from the region bounded by a perfectly conducting sheet of infinitesimal (or small) thickness, the added field outside the surface must be such as to destroy the normal component of the resultant field **H** at the surface: this is obvious because otherwise magnetic tubes of force would enter the shielded region. Figure 4 gives a rough indication of the combined

[33] *Cf.* J. Jeans, The mathematical theory of electricity and magnetism, 5th ed., p. 484, Ex. 1.
[34] Mathematical and physical papers, Cambridge, 1929, **1**, p. 13.

field in the case of a doublet parallel to, and approaching, a perfectly conducting thin plane-sheet; the position of the image-doublet is indicated on the right. When the shielding is only partial, the inclination of the tubes of force to the surface is reduced, though not annulled, by the induced currents, so that *fewer* tubes enter the surface.

7.6—We next consider the mechanical forces arising between the magnetic system and the conductor in whose neighbourhood the magnetic system is moving. One case can be dealt with specially simply, without

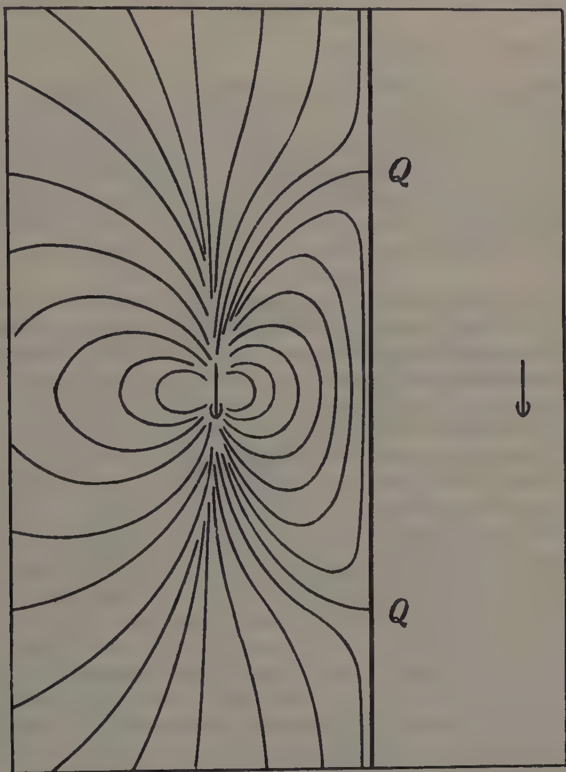


FIG. 4—Meridian section

considering the detailed interaction between the magnetic field and the surface-currents.

Consider a magnetic doublet of moment M, with its axis parallel to the plane-face of a semi-infinite conductor at distance r. When the doublet is approaching the conductor at a rate sufficiently rapid (in relation to the conductivity of the solid) to cause complete shielding within a thin surface-layer, the currents produce a magnetic field, in external space, equivalent to that of a doublet of equal moment M, at a distance $2r$ from the real magnet. The resultant mechanical force F between the magnet and the solid is the same as that between the real doublet and the image-doublet, that is

(27) $$F=3M^2/(2r)^4$$

The work done in bringing the doublet (or the solid) from infinity to the distance r is $\int_{\infty}^{r} F\,dr$, or

(28) $$M^2/16r^3$$

If $r = va$, where a is the Earth's radius, the work done is

(29) $$M^2/16v^3a^3$$

or, inserting numerical values for M and a, it is

(30) $$1.7\times10^{24}/v^3$$

since $M = 8.5\times10^{25}$, $a = 6.37\times10^8$.

7.7—The mechanical force on an element of a conductor carrying an electric current of density $\mathbf{i}$ is $\mathbf{i}_\wedge\mathbf{H}$ per unit volume, where H is the magnetic intensity at the point, and $\mathbf{i}$, $\mathbf{H}$ are measured in electromagnetic units. For a thin rigid infinite perfectly conducting plane-sheet, the mechanical force per unit area is $\mathbf{i}_\wedge\mathbf{H}$, where $\mathbf{i}$ is the current-density in two dimensions; in the case considered in §7.2, this varies from point to point, being a maximum at the point (0, 0, 0), and zero at the limiting points Q.

Suppose the doublet to be at rest, and the thin sheet in normal motion towards it; if the sheet suddenly ceased to be rigid, distortion of the plane would occur. The momentum would initially be the same per unit area all over the plane, but the retardation would vary from point to point, tending to zero at infinity; hence the outlying parts of the sheet would advance relatively to the parts around the origin. The parts near the foci Q of the current-ovals would also advance relatively to O and to other points where the current-density is comparable with that at O. Thus the sheet would tend to be held back in the regions round the origin, except for two "horns" that would tend to form round the points Q. As the sheet approached the Earth, the foci Q of the current-ovals would, if the sheet remained plane, move along a straight line towards the Earth's centre, their mutual distance therefore steadily decreasing. It seems likely that the distance between the horns will likewise lessen, although the sheet becomes distorted as it approaches the Earth. This progressive change of location of the foci Q on the advancing stream-front may somewhat restrict the passage of matter from the rear, through these patches of little or no retardation, into the space on the earthward side of the front; but such passage seems bound to occur. The matter thus passing through seems likely to find its way ultimately towards the polar regions, but a detailed discussion of this point is deferred.

These horns complicate the form of the section of the front of a solar stream in the *terrestrial-meridian* plane through the Sun, but nevertheless the section in this plane must become curved so as to enclose the Earth. The section by the equatorial plane (Fig. 5) will be simpler, and of a roughly parabolic form, the less-retarded sides advancing relatively to the more-retarded centre.

Owing to this distortion of the stream-front, the space shielded from the Earth's field is greater, for a given distance of the centre O of the front from the centre C of the Earth, than if the front remained plane. The greater shielding implies a greater increase in the magnetic energy: it is impossible without detailed calculations to be sure of the magnitude of the increase, but it is perhaps covered by a factor not exceeding 10.

7.8—An estimate of the order of magnitude of the velocity of O can be made by considering the motion of a small element of the surface current-layer around O, supposing the resultant magnetic field near O to be the same as if the stream-front remained plane. The actual field will be somewhat more intense than this, so that our estimated retardation will be somewhat too small.

The origin will now be taken at C the centre of the Earth, and the axis of z will be taken in the direction of motion of the stream. Thus

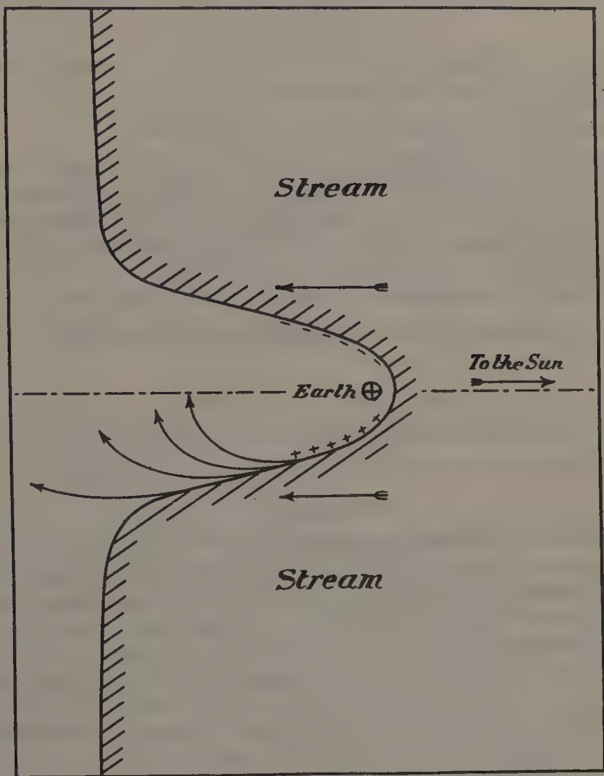


FIG. 5—Equatorial section

the coordinate z of O will be negative while the stream is approaching the Earth, but dz/dt will be positive.

Let v denote the velocity of O at time t, reckoned positively, so that $v = dz/dt$; also let ρ_0, v_0 be the density and velocity of the stream in the undisturbed regions behind the front, which are shielded from the magnetic field. Let m denote the mass of the surface current-layer per unit area. Then, owing to the inflow of matter into the layer

(31) $$dm/dt = \rho_0 \, (v_0 - v)$$

The equation of momentum of the layer is

(32) $$dmv/dt = F + \rho_0 v_0 \, (v_0 - v)$$

where F denotes the electromagnetic retarding force per unit area, and the second term represents the flow of momentum into the layer from

behind. Supposing ρ_0 and v_0 to be constant, (31) and (32) may be combined to give

(33) $$dm(v-v_0)/dt=F$$

The magnetic force in the layer varies from zero (or a low value) on the rear side to twice the normal value H of the Earth's field on the front of the layer; the mean value is therefore H. The total current per unit surface-area of the layer, assuming complete shielding, is $H/2\pi$, so that, apart from a factor of order unity,

(34) $$F=-H^2/2\pi$$

Hence since at distance z from C, $H=a^3H_0/z^3$, where H_0 is the equatorial value of H at the Earth's surface,

(35) $$dm(v-v_0)/dt=-H_0^2a^6/2\pi z^6$$

This equation is troublesome to integrate, and to avoid the difficulty we will introduce a factor v/v_0 on the right; this is equivalent to a reduction in the retarding force, and the results must afterwards be examined to see how far this departure from the actual conditions of the problem is likely to affect the results obtained.

Since $v=dz/dt$, the solution of the modified equation

(36) $$dm(v-v_0)/dt=-(H_0^2a^6/2\pi v_0)(1/z^6)(dz/dt)$$

is

(37) $$m\ (v-v_0)=H_0^2a^6/10\pi v_0 z^5$$

no arbitrary constant being added since $v=v_0$ at $z=-\infty$.

Integrating (31) we have also

(38) $$m=\rho_0\ (v_0t-z)$$

In this equation we shall suppose that (v_0t-z) vanishes at $z=-\infty$, so that (v_0t-z) represents the lag of the centre O of the stream-front, behind the position which it would have occupied had there been no magnetic field; at $z=-\infty$ the magnetic field vanishes and there is no induced current or current-layer; for simplicity we take $m=0$ at $z=-\infty$, and no constant of integration is needed in (38). The vanishing of (v_0t-z) at $z=-\infty$ implies that when O is there, $t=-\infty$. The lag (v_0t-z) will be denoted by z', and both z and z' will be reckoned in Earth-radii a, then being denoted by Z and Z'. Thus

(39) $$Z=z/a,\ Z'=z'/a=(v_0t-z)/a=m/\rho_0a$$

and by (37) and (38)

(40) $$v/v_0=1+1/\gamma Z^5Z'$$

where

(41) $$\gamma=10\pi\rho_0v_0^2/H_0^2$$

But

(42) $$dZ/dZ'=dz/dz'=v(dt/dz')=v/(v_0-v)=-(1+\gamma Z^5Z')$$

by (40).

By writing

(43) $$\zeta=\gamma Z^6/5,\ \phi=dZ/dZ'=-(1+\gamma Z^5Z')$$

so that

(44) $$v/v_0=\phi/(1+\phi)$$

(42) is transformed to

(45) $$d\phi/d\zeta = (5/6)[\phi(1+\phi)-\zeta]/\zeta\phi$$

If ϕ can be determined from (45) as a function of ζ, by (43) and (44) we know v as a function of Z.

The graphs of the solutions of (45) for positive values of ζ consist of a series of curves as shown in Figure 6. The curves all touch the

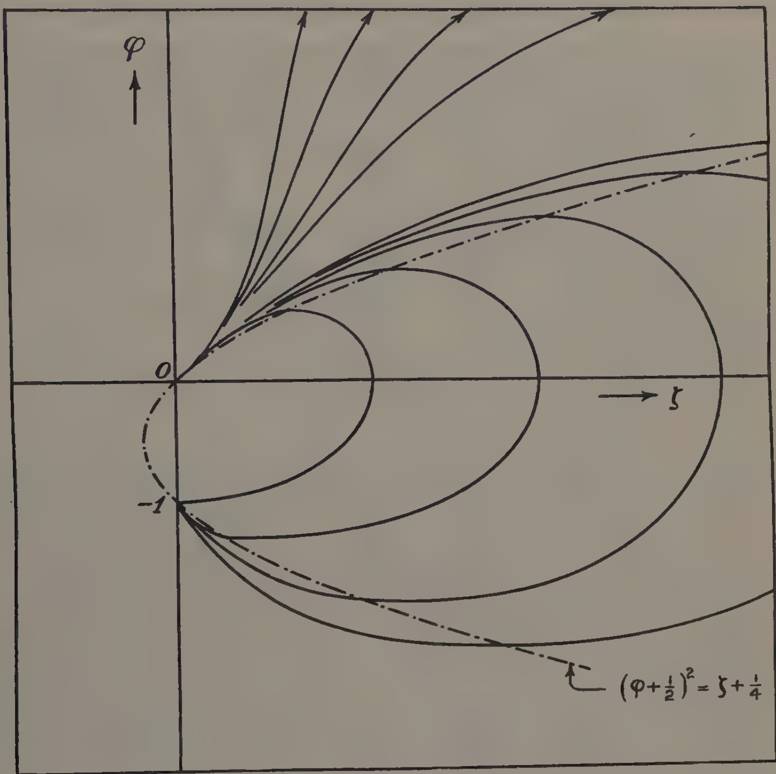


FIG. 6

parabola $\phi^2+\phi-\zeta=0$ or $(\phi+1/2)^2=\zeta+1/4$ at the origin. Some of them tend steadily to infinity; from this maximum they descend so as to cross the ζ-axis at right-angles, after which they converge again to the point $\phi=-1$ on the ϕ-axis. These curves are wholly finite (for $\zeta>0$); some of them have a minimum value lying on the same parabola.

The limiting solution which just goes to infinity is given by the asymptotic equation

(46) $$\phi=\sqrt{(5/2)\zeta}-5/7+(\sqrt{10}/49)(1/\sqrt{\zeta})+\cdots\cdots$$

valid beyond about $\zeta=3$. The other solutions that go to infinity are those of the form $\phi^2=(5/2)\zeta+A\zeta^{5/3}$. At infinity the mass m of the conducting layer (per unit area) is small, and for analytical simplicity can for this purpose be treated as zero, so that there $Z'=0$ (by 39); this condition is equivalent to $A=0$, because

$$Z'=-(1+\phi)/\gamma Z^5=-1/\gamma Z^5-(1/2\gamma Z^4+A/5^{5/3}\gamma^{1/3})^{1/2}$$

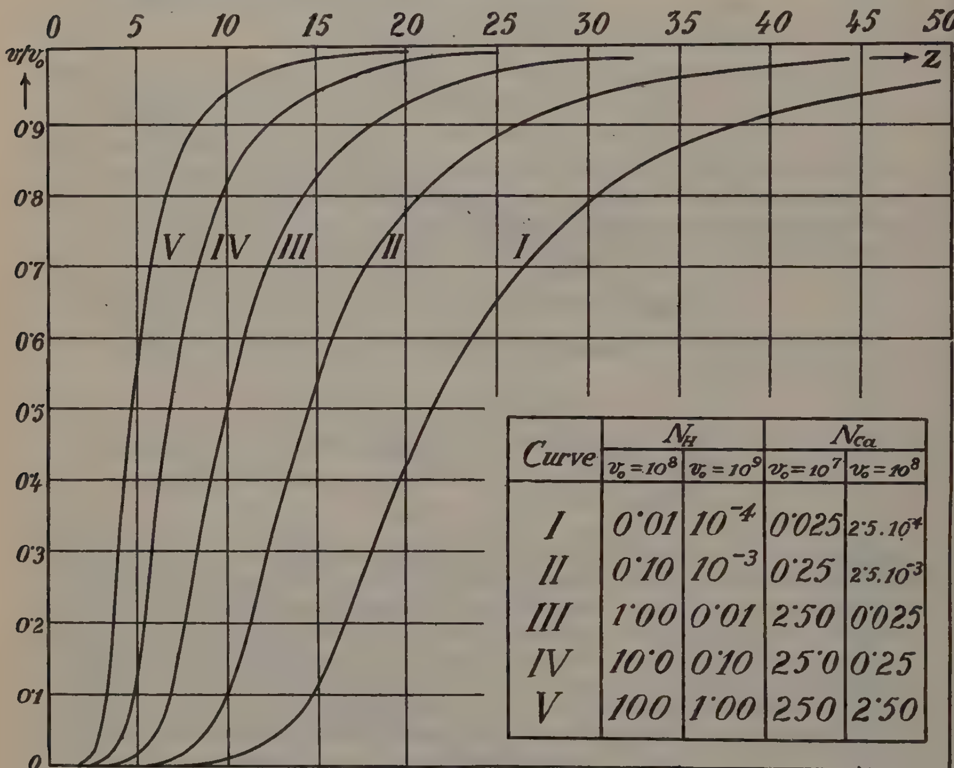
and at $Z=-\infty$ this is not zero unless $A=0$.

The solutions near the origin are of the form

$$\phi=\zeta+(1/5)\zeta^2+\dots \tag{47}$$

the first two terms in this power-series being common to all. The order of mutual contact of the curves at the origin is very high, the complementary function near the origin being approximately $(B/\zeta)e^{-5/6\zeta}$, which tends to zero very rapidly.

The graph of v as a function of z can be drawn for any value of γ



Curve	N_H, $v_0=10^8$	N_H, $v_0=10^9$	N_{Ca}, $v_0=10^7$	N_{Ca}, $v_0=10^8$
I	0·01	10^{-4}	0·025	$2·5.10^{-4}$
II	0·10	10^{-3}	0·25	$2·5.10^{-3}$
III	1·00	0·01	2·50	0·025
IV	10·0	0·10	25·0	0·25
V	100	1·00	250	2·50

Fig. 7

by using the solutions (46) and (47) for large and small values of z, and joining the two parts of the curve, the interpolation offering no difficulty. Owing to the vanishing of the constant A, the nature of the solutions depends only on the parameter γ, which is proportional to the kinetic energy-density of the undisturbed stream.

In Figure 7 five curves are drawn to illustrate the dependence of v/v_0 upon z (or z/a) for various values of γ; the range over which the curves are drawn by interpolation is between $v/v_0=0.1$ and $v/v_0=0.7$. The values of γ are expressed in terms of the number N of hydrogen or calcium atoms per cc, moving with various velocities v_0, from 10^7 to 10^9 cm/sec, necessary to supply the corresponding value of γ or $\rho_0 v_0^2$, taking $H_0=0.3$. The values of N vary inversely as v_0^2.

It must be remembered that the curves are only approximate, because the retarding force F is underestimated to the extent of the factor

v/v_0. For $v/v_0 > 0.8$ the error is not serious, but for lower values of v/v_0 the curves must bend downwards increasingly more steeply than in the Figure. This, however, is not likely to make much difference in the distance at which v/v_0 is reduced to 0.1 (say), particularly in the case of the denser streams.

At first the decrease of velocity of the stream front is very slight, but from $v/v_0 = 0.9$ it is rapid until $v/v_0 = 0.1$, after which the further decrease to zero is gradual; this is because of the great mass then accumulated

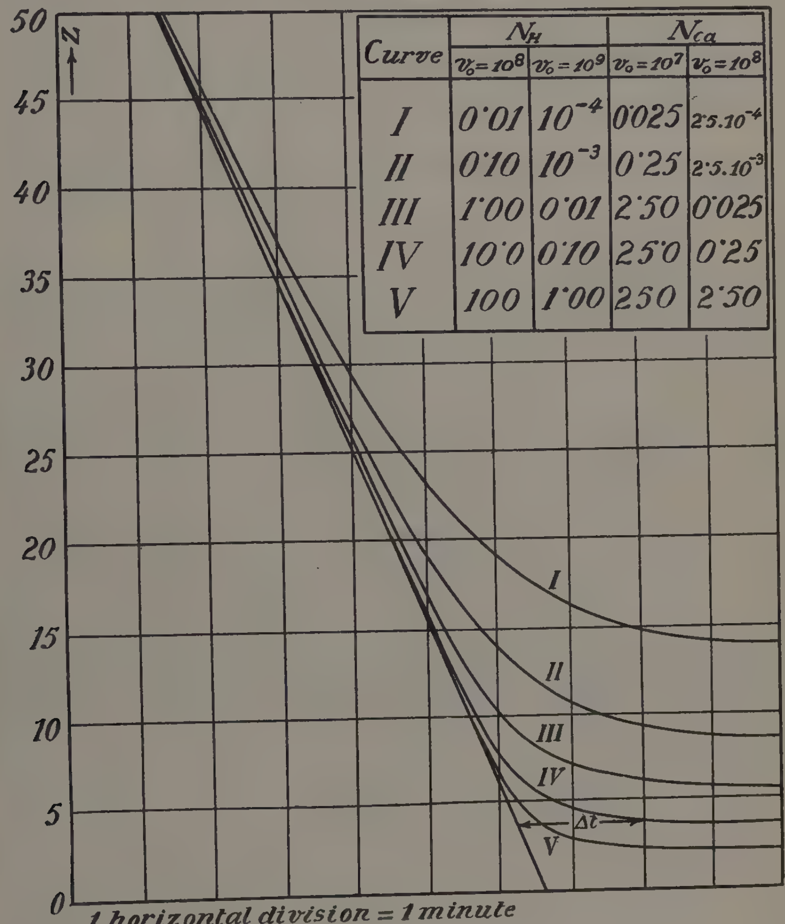


FIG. 8

in the stream-front; it is at this part of the curve that the approximations made are most seriously in error, though not sufficiently to alte the general character of the result.

The following Table gives the calculated distance—an underestimate—at which v/v_0 has fallen to 0.1, in the case of hydrogen atoms for which $v_0 = 10^8$.

$N = 0.01$	0.1	1	10	10^2	10^3	10^4	10^5
$Z = z/a = 14.7$	10.0	6.8	4.7	3.2	2.2	1.5	1.0

It is clear that only in the case of the lower densities is the retardation sensitive to a change of density.

Figure 8 illustrates the time taken for the stream-front to approach the Earth. The time-origin has no special significance in this diagram, only the time-intervals being of importance. The straight line represents the travel of the stream-front if unaffected by the field; it corresponds to $v_0 = 10^8$ cm/sec, or about 10 Earth-radii per minute. The curved lines refer to the streams retarded as calculated; the retardation *in time*, at any distance, is measured by the difference between the straight line and the curve. The rapid bend in the curves corresponds to the sudden decrease in velocity mentioned above; after this stage the approach to the Earth is slow, especially for the denser streams, which, however, are but little retarded till they are within a few radii from the Earth.

7.9—At Z Earth-radii, the Earth's magnetic intensity in the equatorial plane is $0.3/Z^3$, while the change in the Earth's field due to an image-doublet at distance $2Za$ (corresponding to a distance Za for a plane conducting sheet producing complete shielding) is $0.3/(2Z)^3$. This is of magnitude 30γ or 0.0003Γ when $Z=5$; now 30γ is the order of magnitude of the initial rise of horizontal magnetic force during an ordinary magnetic storm; if we identify this rise with the field of the image-doublet here considered, it is of interest to consider how quickly this rise will occur. This is approximately the time taken for the stream-front to travel from $Z=10$ (where at the Earth's centre the field of the image-doublet is $0.3/(20)^3$ or about 4γ) to $Z=5$. From Figure 8 it appears that this time is only about a minute, or less, if $N>10$, but that if $N<1$ it may be many minutes, or even hours. This calculation is faulty because the retardation has been underestimated, so that on this account the times mentioned must be somewhat lengthened (though by very little if $N>10$); on the other hand the increase in H due to the distortion of the front of the stream has not been allowed for. Further, the secondary effects of currents induced in the atmosphere of the Earth by the varying field of the image-doublet have not been considered. So far as the present calculations go, however, the value of N for storms having marked sudden commencements would appear to be greater than 10 for hydrogen atoms having velocities 10^8 cm/sec (the corresponding limit for other types of ion and other velocities can be readily inferred).

(*To be continued*)

GEOPHYSICAL STEREOGRAMS

By J. Bartels

Abstract—The use of stereograms for the representation of geophysical data is discussed. Formulae and practical rules for constructing stereograms and anaglyphs (stereoscopic drawings in two colors) are given. Ten sample stereograms, based on unpublished material, are reproduced and discussed. With the exception of No. 1, which illustrates the principle of construction, and No. 10, which shows upper-air currents at Apia, Samoa, the stereograms bear on magnetic phenomena, namely: Nos. 2 to 5—Diurnal and annual magnetic variation at Watheroo (Australia); No. 6—Changes during part of a magnetic storm; No. 7—Differences of the mean magnetic vector on disturbed and quiet days at Potsdam, 1915 to 1928; No. 8—World-chart of secular variation for 1925; No. 9—Globe showing magnetic axes of the Earth, and distribution of magnetic observatories. While some of the stereograms present only new illustrations of well-known facts, the discussions which accompany Nos. 4 to 8 suggest some novel points.

1. *Use of stereograms*

Ordinary plane drawings and curves are inadequate for representing phenomena in three dimensions. This is keenly felt in several branches of geophysics, especially in terrestrial magnetism, where the changes in time and space affect all three components of the magnetic field-vector. Examples of this kind are numerous; a striking case is given by the violent changes which occur during a magnetic storm. A great deal of imaginative power and training is required to form a true conception from the magnetograms which show declination, horizontal intensity, and vertical intensity as functions of time. These difficulties are serious enough to hamper the use of observational material for the advance of theory.

In order to meet this necessity, recourse was taken to stereoscopic drawings. After some trials, a simple method was worked out for producing stereograms which convey a vivid impression of the actual phenomena. Since such stereograms may be useful in many cases for visualizing three-dimensional relations, the general principles of stereoscopic drawings will be outlined, and the necessary formulae will be given in some detail. This part of the paper is of course not claimed to be original in its results, but since they can be deduced in a simple form, these paragraphs were inserted for the convenience of the reader.

Any available stereoscope may be used for inspecting the stereograms which accompany this paper;[1] good results were obtained here with a Wheatstone lens stereoscope made by Carl Zeiss, Jena, using lenses of 15-cm focal distance. If none be at hand, it is sufficient to view the graphs through two lenses of about 7 dioptrics. Care should be taken to fix the stereogram in such a position that the lines connecting equivalent points in the component pictures are exactly parallel to the line connecting the eyes of the observer.

2. *General principles*

The direct perception of relative distances, as obtained by simultaneous vision with both eyes, is the result of an unknown physiological

[1] That the ten stereograms included in this paper may be available for such inspection, spare prints on loose sheets are included.

process connected with the dissimilarity of the images produced in the left and the right eyes. Figure A shows the ground-plan of a three-dimensional object (model) viewed with both eyes, A_1 and A_2. Suppose a vertical transparent plate T is inserted between the eyes and the model. Draw on this plate the projections of the model as seen from A_1 and A_2; these two images I_1 and I_2 are formed by the intersections of the plate with all the straight lines connecting A_1 and A_2 with significant points and lines of the model. If, then, the model be removed, and care is taken that the image I_1 is offered only to the left eye A_1, and I_2 only to the right eye A_2, the observer will still have the impression of viewing the solid model in its original place. The two-plane component pictures I_1 and I_2 in their proper relative position, constitute a stereogram.

The condition that each eye may see only the proper component picture can be met in two different ways. In most ordinary stereograms, the plate T is assumed so near to the eyes, that the left and right component pictures do not overlap in the middle; this is the case in Figure A. In *anaglyphs*, the plate T is assumed near or even behind the model; I_1 and I_2 are drawn in different colors, for example, I_1 red, I_2 green; viewed through corresponding color-filters, using green for the left eye and red for the right eye, I_2 disappears for A_1 and I_1 for A_2.

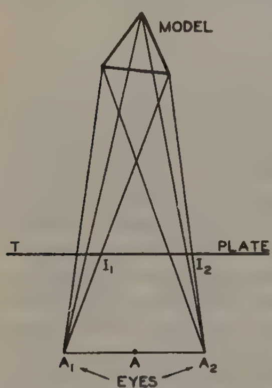


FIG. A

The fusion of the two component pictures is effected with greater ease, if any strain on the eyes is avoided. Near objects are viewed with a greater inclination between the optical axes of the two eyes than far objects. Lifelong experience has trained the eyes to connect automatically the inclination of the axes which is proper for a certain distance of the object with the proper accommodation of each eye. So, in viewing a stereogram directly, each eye is adapted to the distance between eyes and plate in order to see the images distinctly, while the model appears to be at a distance for which a different accommodation of each eye would be necessary. This conflict between the accommodation for the component pictures and that for the imaginary solid picture is detrimental to the impression of depths. It is overcome in stereoscopes by the use of lenses; while the distance between eyes and plate (or stereogram) is maintained corresponding to the conditions of the drawing, the lenses produce distinct images of the component pictures with the eyes accommodated to objects farther away. In anaglyphs, no lenses are used; it is therefore of advantage to keep the model near the plate or the plane of the drawing and to draw heavy lines in faint colors. In viewing anaglyphs, most persons take some time to get the stereoscopic impression; but the effect is especially striking, since the model appears to be suspended in mid-air. The impression is improved by some training.

Stereograms were first drawn by Ch. Wheatstone in 1838. W. Rollmann was the first (in 1853) to draw the component pictures in different colors, which were later called anaglyphs by French authors.[2]

[2] M. von Rohr, Die binokularen Instrumente. Zweite Auflage. Berlin, J. Springer (1920). Gives an exhaustive account of the history of stereoscopic instruments. See also Helmholtz's Treatise on physiological optics, **3**, 281-400, Optical Society of America (1925).

The latest drawings are given in M. v. Laue and R. von Mises, Stereoskopbilder von Kristallgittern, Berlin, J. Springer (1926). The method used is described by H. Pollaczek-Geiringer, Zs. angew. Math., Mech., **6**, 70-73 (1926); the same method, with slight modifications, is used in the present paper.

3. *The calculation of stereograms*

The component pictures are nothing but perspective drawings, the corresponding far-points of which are shifted by an amount equal to the mean distance between the points of rotation of the human eye. Since the two components differ very slightly, ordinary perspective drawings would be too inaccurate. Therefore, significant points of the stereogram are throughout calculated in rectangular coordinates, drawn in an enlarged scale[3] (mostly 5-fold), and reduced photographically to the size of ordinary stereograms.

The model is supposed to be given by its rectangular coordinates (see stereogram 1); O is the origin, and the coordinates are ξ forward, η to the right, ζ downward. A_1 and A_2 are the eyes, their distance $\overline{A_1A_2}$ may be called $2a$, so that $\overline{A_1A}=\overline{AA_2}=a$. The plate is vertical and parallel to $\overline{A_1A_2}$. M_1, M, and M_2 are the intersections of the perpendiculars drawn from A_1, A, and A_2; M_1, M_2, the far-points, are chosen as the origins of two plane coordinate-systems, y_1, y_2 to the right, and z_1, z_2 downward. P, with the coordinates ξ, η, ζ, may be a point of the model; we require the coordinates y_1, z_1, and y_2, z_2 of its images P_1 and P_2; that is, of the intersections of the rays A_1P, and A_2P with the plate.

The lines $\overline{A_1M_1}$, $\overline{AM}$, and $\overline{A_2M_2}$ may intersect the vertical plane through O in N_1, N, and N_2, and the vertical plane through P in S_1, S, and S_2; Q and R are the intersections of the vertical lines through O and P with the horizontal plane through A_1 and A_2. The following designations are used: $\overline{A_1A_2}=2a=$distance between the eyes (taken as 65 mm); $\overline{AM}=t=$plate-distance; $\overline{AN}=d=$model-distance; $\overline{QN}=s=$lateral shift —positive if N is to the right of Q; and $\overline{QO}=v=$vertical shift —positive if O is below Q. The distances of the eyes from the plate and from the vertical plane through P are t and $(d+\xi)$, respectively. Therefore, the image of all points lying in the vertical plane through P is an exact reduction in the ratio $t/(d+\xi)$ with the points M_1 and S_1 as homologous centers of the reduction for the left eye, and M_2 and S_2 for the right eye. Thus

(1) $$y_1/S_1R=z_1/RP=t/(d+\xi) \text{ and } y_2/S_2R=z_2/RP=t/(d+\xi)$$

With $S_1R=(\eta-s+a)$, $S_2R=(\eta-s-a)$ and $RP=(\zeta+v)$, we have

(2) $$y_1=t(\eta-s+a)/(d+\xi),\ y_2=t(\eta-s-a)/(d+\xi), \text{ and } z_1=z_2=(\zeta+v)/(d+\xi)$$

These are the coordinates of the stereogram. The drawing may be enlarged in the ratio $m/1$. A convenient form for calculating the coordinates my and mz in these enlarged drawings, as measured from two points (corresponding to M_1 and M_2) $2ma$ apart, is easily obtained from (2) by putting

(3) $$f=1/[(\xi/mt)+(d/mt)]$$

whence,

(4) $$my_1=(\eta-s+a)f,\ mz_1=mz_2=(\zeta+v)f, \text{ and } m\Delta y=m\ (y_2-y_1)=-2af$$

The whole difference between the two component pictures is given by Δy.

[3] Cross-section paper made by C. Schleicher and Schüll, Düren, Germany, with millimeter-squares printed in a non-actinic blue color, was found to be sufficiently accurate and very helpful.

Sometimes the model gives a better impression if it is turned about the ζ-axis, so that the ξ and η coordinates are transformed into ξ^* and η^*. For numerical work it is convenient to use the angle so that either

(5a) $$\xi=0.8\xi^*-0.6\eta^* \text{ and } \eta=0.6\xi^*+0.8\eta^*$$

or

(5b) $$\xi=\xi^*+0.1\eta^* \text{ and } \eta=\eta^*-0.1\xi^*$$

It is convenient to arrange the coordinate-system so that the model is near the origin, and ξ is usually positive. The lateral shift s is a constant, which is in general small and serves only to save computation; for instance, with $a=32.5$ mm, s is chosen as 2.5 mm so that $(\eta-s+a)=\eta+30$ mm. In order to get a better view of the model, the vertical shift v can be chosen in a fairly large range, from $+d/2$ to $-d/2$, without disturbing the natural impression.

Each stereogram is of course identical with a stereoscopic photograph of the model, taken with the lenses of a twin-camera at A_1 and A_2, and the photographic plate at the distance t behind A_1 and A_2; the focal distance of the lenses must be nearly equal to t; in fact, slightly less. The left and right component pictures appear exchanged on the photograph.

In order to avoid overlapping of the component pictures in ordinary stereograms, a convenient rule is derived as follows: Suppose the nearest points of the model to have the abscissae $\xi=0$, and the model may not be situated completely to the left or the right of the central line AN. The greatest and smallest values of η which can be admitted, may be η' and η''. Then it is sufficient that the image of a point $(\xi=0,\ \eta=\eta')$ in the left component picture is situated to the left of the image of a point $(\xi=0,\ \eta=\eta'')$ in the right component picture. y_1' (positive) and y_2'' (negative) may be the horizontal coordinates of these images in the stereogram; since they are measured from M_1 and M_2, respectively, and $\overline{M_1M_2}=2a$, the condition is $(y_1'-y_2'')<2a$; or, if we use (2), with $\xi=0$, $(t/d)\ (\eta'-s+a)-(t/d)\ (\eta''-s-a)<2a$, and

(6) $$(\eta'-\eta'')<2a(d/t-1)$$

The vertical extent of the model may be chosen greater—as much as double size if necessary. No restriction is necessary for positive values of ξ; though the impression is better if the range of ξ is not larger than that of η or ζ.

Stereograms with $d=5t$ make a normal impression. From (6) it follows that the lateral extent of the model must then be less than $65\times4=260$ mm. The value t was chosen as 250 mm (stereograms 2 and 3), 200 mm (stereogram 1), and 150 mm (stereograms 4, 5, and 6); the last value seems to give the best results.

In the construction of stereogram 8, some difficulty arose because of the fixed size of the given base-map. The condition (6) would have imposed $d=8t$, with $t=150$ mm and $d=1200$ mm; because of the comparatively small depth of 80 mm of the model, this distance would have been too great to give a good stereoscopic effect. Therefore, a giant was imagined with an eye-separation of $2a=170$ mm, about $8/3\times64$ mm. Then $d=3t=450$ mm was possible; the giant stereogram was afterwards reduced in the ratio 64/170.

4. *Hints for drawing*

Good stereoscopic effects are obtained when the following rules are observed.

(*a*) It sometimes occurs that points lying before or behind a certain line of the diagram seem to be situated on this line in one component picture but not in the other. It is then advisable to interrupt the line near this point in order to get an unobstructed view of the point. The coordinates of the breaks in the line must be calculated; for all lines which are not too near the horizontal direction, it is most convenient to take the same z-coordinates for the breaks in both components (see stereograms 7 and 9).

(*b*) The distance of lines which are nearly parallel to A_1A_2 can only be judged from characteristic points on them; for instance, their ends. This is the well-known effect occurring, for instance, if telephone-wires are observed from below and well between the poles. If the line A_1A_2 connecting both eyes is parallel to the wires, the observer is unable to judge the position of the wires in space, but the stereoscopic impression is immediately obtained if A_1A_2 is turned perpendicular to the wires. Important lines which are nearly parallel to A_1A_2 are therefore better marked by equidistant points on them (see stereogram 7).

(*c*) Lines and planes of the model, which cut A_1A_2 between A_1 and A_2 are better avoided, because they present different faces to both eyes. Some transformation of coordinates like (5*b*) is useful in such cases; (5*b*) has been applied in the stereograms 7 and 10.

(*d*) Curved lines are better not drawn in full, but indicated by characteristic points; for example, as the meridians in stereogram 9.

5. *Description and discussion of the stereograms*

The spectrograms here described and discussed are given in the order of their numbers on Plates 2 to 4. (In cutting out stereograms for viewing by a stereoscope they should be cut on the horizontal lines indicated below each.)

The magnetic stereograms 2 to 6 are all based on hitherto unpublished data and computations relating to the Watheroo Magnetic Observatory of the Department of Terrestrial Magnetism, and stereogram 7 on unpublished computations of data obtained at the Prussian Potsdam Observatory. Stereograms 8 and 9 are based on materials assembled at the Department of Terrestrial Magnetism. The material for stereogram 10 relating to upper-air currents at Apia, Samoa, to a height of 12 kilometers was supplied by A. Thomson, formerly Director of the Apia Observatory. To amplify the following brief descriptions and discussions of the stereograms, the reader is referred to any of the texts on terrestrial magnetism.[4]

Stereogram 1 illustrates the principle involved in the calculation of stereograms which has been described in section 3.

Stereograms 2 to 6 represent terrestrial magnetic data as obtained at the Watheroo Magnetic Observatory in Western Australia of the Carnegie Institution of Washington. They give the change in time of the magnetic vector which is supposed to be drawn from a fixed origin, and the movement in space of the end of the vector is shown. The

[4] For example, Encyclopaedia Britannica, 14th ed., **17**, 353-385 (1911); Wien-Harms, Handbuch der Experimentalphysik, **25**, I (1928).

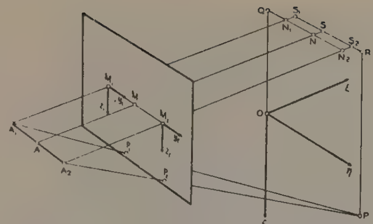
observer is looking towards the north, and east is, therefore, on the right side.

Stereograms 2 and 3—The diurnal magnetic variations at Watheroo in southern winter (May to August) and in southern summer (November to February) as determined from the international quiet days (five per month) for the years 1920 to 1924, during which period the average relative sunspot-number was 21, are shown in stereograms 2 and 3. It is to be noted these are based on *apparent* local time. Each hourly value is marked by a small circle and every third hour by a double circle—N indicating apparent noon and M apparent midnight. Connecting lines for the daylight hours 6 to 18 (6 p. m.) are drawn heavier than those for the night hours. The scale is shown by the cube which is oriented true north, east, and vertical, the length of the edge corresponding to 20γ in stereogram 2 and to 60γ in stereogram 3. Correction for non-cyclic change was applied to the data before preparing the stereographic drawings. The mean value for the whole day is shown in black in the center of the cube, near M. The direction of the average field-vector is indicated by the line which comes from below and from the south, ending in the center of the cube. The length of this line between the mark (horizontal bar) and the end represents, in stereogram 2, 14.2γ, or exactly one four-thousandth of the entire field-intensity; in other words, the fixed origin from which the field-vector is assumed to be drawn lies on this line 4,000 times this distance downward and towards the south. In stereogram 3, the length of the line corresponds to one two-thousandth of the entire field-intensity.

The stereograms show that the large changes are in the daytime, while the small changes are at night. The daytime values deviate much more from the daily mean than the night values. The winter-curve has a second loop, which disappears in summer. The summer-curve has about two times as large an amplitude as the winter-curve. While the summer-curve is nearly confined to the east-west vertical plane, the winter-curve shows marked movements towards north and south. The movement from west to east in the daytime is similar in both seasons, but the summer-curve passes corresponding points more than an hour earlier than the winter-curve.

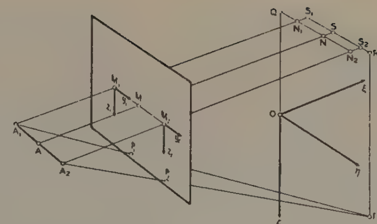
Stereograms 4 and 5—For stereograms 4 and 5, showing annual magnetic variation at Watheroo, the normal values were computed (following Ad. Schmidt[5]) as the mean values of 12 months and ascribed to the center of this interval. Deviations of the single monthly means from the normal values in the middle of the month were formed and averaged for the ten years 1919.5 to 1929.5. These averages were smoothed according to $b' = (a+b+c)/3$ and are represented in stereogram 4, in which the months are indicated by Roman numerals I to XII. The direction of the mean annual vector is indicated by the full line leading from below and from the south to the center of the diagram. The edges of the cubes correspond to 10γ—two such cubes are drawn behind one another. The two portions with 12-month and 6-month periods are shown separately. The 12-month or annual period, represented by half the differences (I−VII) = January minus July, etc., is drawn in stereogram 5 on the left, and the 6-month or semi-annual period, represented by half the sums (I+VII) = January plus July, etc., on

[5] Ad. Schmidt, Ergebnisse der magnetischen Beobachtungen in Potsdam und Seddin, 1900-1910. Berlin, Abh. met. Inst., 5, No. 3, 11, and 30 (1916).



PRINCIPLE OF THE CALCULATION OF STEREOGRAMS

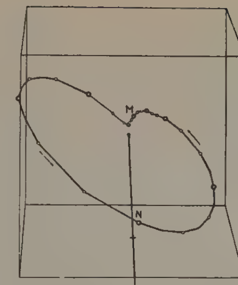
A_1, A_2, LEFT AND RIGHT EYE; P, POINT IN MODEL WITH COORDINATES ξ, η, ζ
P_1 AND P_2, IMAGES OF P IN LEFT AND RIGHT COMPONENT PICTURES OF STEREOGRAM WITH COORDINATES Y_1, Z_1 AND Y_2, Z_2



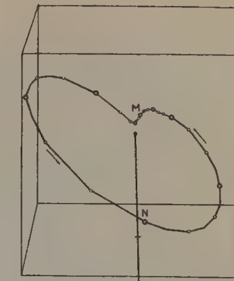
PRINCIPLE OF THE CALCULATION OF STEREOGRAMS

A_1, A_2, LEFT AND RIGHT EYE; P, POINT IN MODEL WITH COORDINATES ξ, η, ζ
P_1 AND P_2, IMAGES OF P IN LEFT AND RIGHT COMPONENT PICTURES OF STEREOGRAM WITH COORDINATES Y_1, Z_1 AND Y_2, Z_2

STEREOGRAM 1

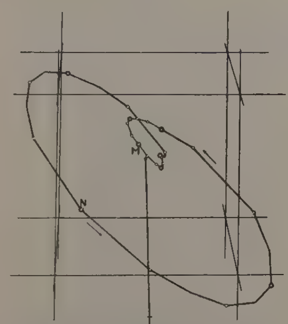


DIURNAL MAGNETIC VARIATION AT WATHEROO
IN SOUTHERN SUMMER (NOVEMBER TO FEBRUARY)
MAGNETICALLY-QUIET DAYS—MEAN 1920-24, N-NOON, M-MIDNIGHT
EDGE OF CUBE, 60γ, LOOKING NORTH

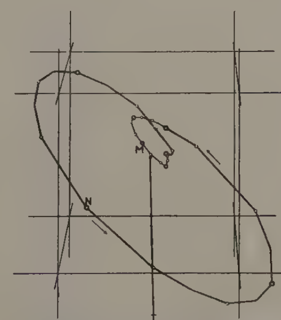


DIURNAL MAGNETIC VARIATION AT WATHEROO
IN SOUTHERN SUMMER (NOVEMBER TO FEBRUARY)
MAGNETICALLY-QUIET DAYS—MEAN 1920-24, N-NOON, M-MIDNIGHT
EDGE OF CUBE, 60γ, LOOKING NORTH

STEREOGRAM 2

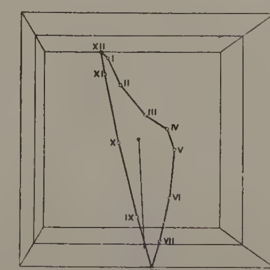


DIURNAL MAGNETIC VARIATION AT WATHEROO
IN SOUTHERN WINTER (MAY TO AUGUST)
MAGNETICALLY-QUIET DAYS—MEAN 1920-24; N-NOON, M-MIDNIGHT
EDGE OF CUBE, 20γ; LOOKING NORTH

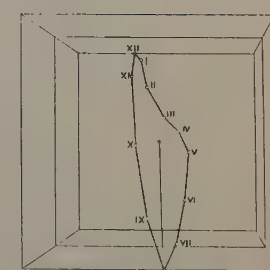


DIURNAL MAGNETIC VARIATION AT WATHEROO
IN SOUTHERN WINTER (MAY TO AUGUST)
MAGNETICALLY-QUIET DAYS—MEAN 1920-24; N-NOON, M-MIDNIGHT
EDGE OF CUBE, 20γ; LOOKING NORTH

STEREOGRAM 3



ANNUAL MAGNETIC VARIATION AT WATHEROO
MEAN 1919-28, MONTHS INDICATED BY ROMAN NUMERALS, EDGE OF CUBES, 10γ



ANNUAL MAGNETIC VARIATION AT WATHEROO
MEAN 1919-28, MONTHS INDICATED BY ROMAN NUMERALS, EDGE OF CUBES, 10γ

STEREOGRAM 4

the right. The broken lines in stereogram 5 are parallel to the magnetic axis of the Earth.

The east component is little affected by the annual variation, yet the deviations from the meridian are bigger and more systematic than could be expected from the fact that the declination in Watheroo is only 4°.3 west, and the horizontal direction towards the pole of the magnetic axis is only 1°.3 east of north. The magnetic vector is more intense in the southern summer months, especially in December; this accounts for the 12-month component of the variation to be noted in stereogram 5, left. The semi-annual variation is smaller; it shows a decrease of the vector in the equinoctial months.

The discussion of the annual magnetic variation at Potsdam by Ad. Schmidt[5] appears in a different light when these observations from the southern hemisphere are considered. The semi-annual part is similar in both hemispheres, a decrease of the north component during equinoxes, due to the higher frequency of disturbances, with their characteristic depression in horizontal intensity. But the 12-month component obviously depends on the season of the respective hemisphere and is described as an increase of horizontal intensity in summer and a decrease in winter.

This 12-month component is probably related to the higher average ionization over the summer-hemisphere. But definite statements will only be possible when a greater number of stations are considered. Unfortunately, it will be rather difficult to find the pure seasonal effect, since the deviations of single monthly means from their normal value depend largely on magnetic activity. When the internal and external parts of the field can be separated accurately enough, the annual variation, because of its long period, may give an interesting example for the application of the theory of induced currents within the Earth.

Stereogram 6—Changes of the magnetic vector at Watheroo during part of the magnetic storm of January 30, 1924, from $1^h\,00^m$ to $2^h\,30^m$ Greenwich mean time ($8^h\,41^m$ to $10^h\,11^m$ local mean time) are shown in stereogram 6. This interval was selected because of some typical oscillations with a period of about 15 minutes. The original records of declination, horizontal intensity, and vertical intensity (D, H, and Z) were measured at intervals of five minutes and, in addition, at characteristic points and at maxima or minima of the curves. The results were expressed in north, east, and vertical (downward) components (X, Y, and Z) in deviations from the mean value for the whole interval of 90 minutes. These values are shown in the ordinary way in Figure B, namely, X, Y, and Z, as functions of time; comparison of this diagram with the stereogram illustrates the advantage of the latter. In the stereogram the times $1^h\,00^m$, $1^h\,05^m$, $1^h\,10^m$, etc., are marked by small circles, while the intermediate points bear no marks. The edge of the cube is 60γ; lines from the origin of the magnetic vector, parallel to the mean vector, come up from below and from the south and are drawn to end in the two far lower corners of the cube.

The movement of the vector consists of four loops which are described in the same sense. The first two, from $1^h\,00^m$ to $1^h\,30^m$, are very similar. The movement is specially violent from $1^h\,30^m$ to $1^h\,45^m$, and subsides after $2^h\,05^m$. It would be valuable to deduce electric current-vortices, which caused these changes in the magnetic vector, from the observations at a greater number of stations; in fact, so far as records

have been published, this interval was marked by similar oscillations all over the globe.

Stereogram 7—Differences of the mean magnetic vector on disturbed and on quiet days at Potsdam, from data for 1915 to 1928 are illustrated in stereogram 7. The magnetic observations at about 40 observatories all over the globe are used by the observatory at De Bilt (Utrecht) for selecting, in each calendar month, the five days on which magnetic conditions were most quiet, as also the five days on which they were most disturbed. These days will be referred to as *Q*-days and *D*-days, respectively. They are intervals of 24 hours between successive Greenwich midnights. The mean magnetic vector on the *D*-days differs

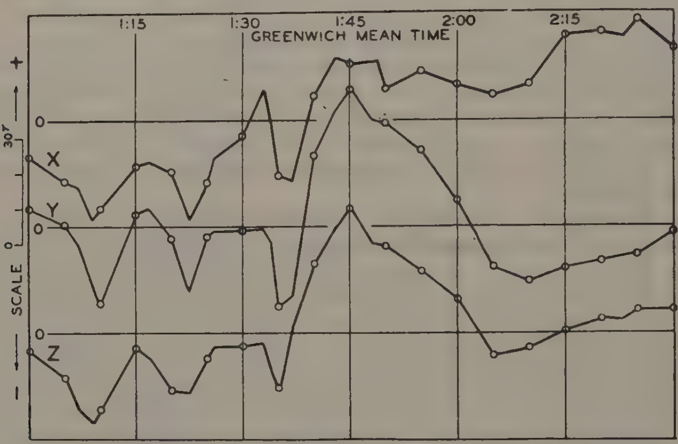


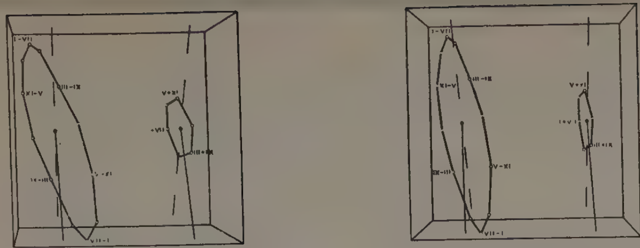
FIG. B

systematically from that of the *Q*-days. The stereogram is intended to bring out these differences.

On the average, about one day out of three calendar days is selected as either a *Q*-day or *D*-day. This will recall that among the *D*-days are many which are only slightly disturbed; or, in other words, that the average intensity of magnetic activity on *D*-days is well below the activity during real magnetic storms in most months.

From the Potsdam yearbooks, the average differences of the magnetic components in the sense *D* minus *Q* were formed for each season, namely: Southern solstice (S. S.), November to February; equinoxes (E.), March, April, September, October; northern solstice (N. S.), May to August, and for each year.

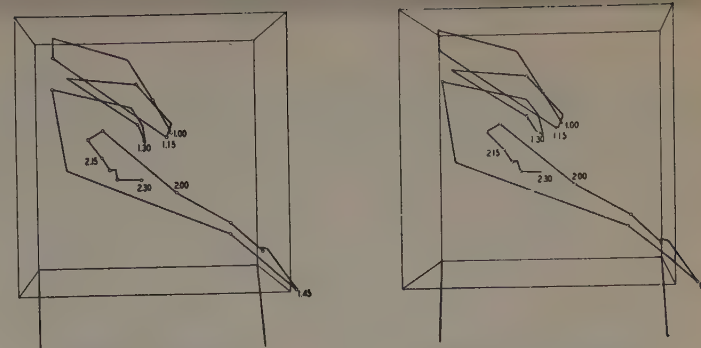
In the lower part of the stereogram, the average differences for each year have been plotted. The two cubes, one behind the other, are orientated north (forward), east (to the right) and vertical. The edge of each cube represents 10γ, so that the edges pointing north represent 20γ in all. The point *Q* in the far upper left-hand corner represents the origin of the difference-vectors. The line *FQ* represents the last part of the mean magnetic vector on *Q*-days. It points northward and downward, and its total length would be about $46{,}800\gamma$. From *Q* the difference-vectors $(D-Q)$ have been plotted and indicated by their end-points.



ANNUAL MAGNETIC VARIATION AT WATHEROO RESOLVED INTO PERIODS OF 12 (LEFT) AND 6 (RIGHT) MONTHS
BROKEN LINE IS PARALLEL TO EARTH'S MAGNETIC AXIS; EDGE OF CUBE, 10γ

ANNUAL MAGNETIC VARIATION AT WATHEROO RESOLVED INTO PERIODS OF 12 (LEFT) AND 6 (RIGHT) MONTHS
BROKEN LINE IS PARALLEL TO EARTH'S MAGNETIC AXIS; EDGE OF CUBE, 10γ

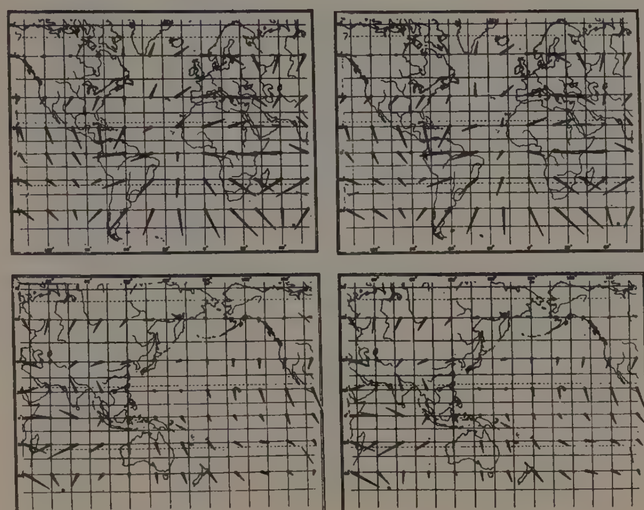
STEREOGRAM 5



IRREGULAR VARIATIONS AT WATHEROO DURING PART OF A MAGNETIC STORM
JANUARY 30, 1924, 1^h00^m TO 2^h30^m GMT
CIRCLES AT 5-MINUTE INTERVALS; EDGE OF CUBE, 60γ

IRREGULAR VARIATIONS AT WATHEROO DURING PART OF A MAGNETIC STORM
JANUARY 30, 1924, 1^h00^m TO 2^h30^m GMT
CIRCLES AT 5-MINUTE INTERVALS; EDGE OF CUBE, 60γ

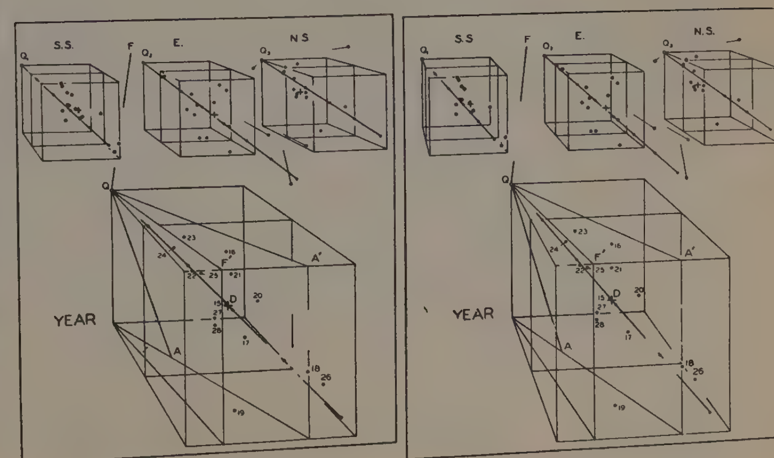
STEREOGRAM 6



WORLD CHART OF SECULAR VARIATION FOR 1925
SHOWS, AT POINTS 20° APART,
THE RESULTANT OF THE ANNUAL MAGNETIC CHANGE (SECULAR VARIATION)
PERPENDICULAR LINES NEAR CORNERS REPRESENT 100γ UPWARD AND 100γ DOWNWARD
THE CHART-DISTANCE FOR 15° IN LONGITUDE CORRESPONDS TO 61γ

WORLD CHART OF SECULAR VARIATION FOR 1925
SHOWS, AT POINTS 20° APART,
THE RESULTANT OF THE ANNUAL MAGNETIC CHANGE (SECULAR VARIATION)
PERPENDICULAR LINES NEAR CORNERS REPRESENT 100γ UPWARD AND 100γ DOWNWARD
THE CHART-DISTANCE FOR 15° IN LONGITUDE CORRESPONDS TO 61γ

STEREOGRAM 8



DIFFERENCES BETWEEN MAGNETICALLY-DISTURBED AND MAGNETICALLY-QUIET DAYS AT POTSDAM
ABOVE, FOR THE SEASONS, BELOW FOR THE YEARS 1915, 1916, 1928
EDGES OF ALL CUBES, 10γ LOOKING NORTH; OA, PARALLEL TO MAGNETIC AXIS
FQ, LOWER END OF MEAN MAGNETIC VECTOR; OQ, VECTOR OF AVERAGE DIFFERENCE

DIFFERENCES BETWEEN MAGNETICALLY-DISTURBED AND MAGNETICALLY-QUIET DAYS AT POTSDAM
ABOVE, FOR THE SEASONS, BELOW FOR THE YEARS 1915, 1916, 1928
EDGES OF ALL CUBES, 10γ LOOKING NORTH; OA, PARALLEL TO MAGNETIC AXIS
FQ, LOWER END OF MEAN MAGNETIC VECTOR; OQ, VECTOR OF AVERAGE DIFFERENCE

STEREOGRAM 7

Each point—for instance, the point marked 17, which represents 1917—gives the excess of the average magnetic force on the 60 international disturbed days in this year over the average force on the 60 international quiet days. The value of this difference-vector in the average for the 14 years is marked by a cross and the letter D; the vector QD is drawn and extended beyond D, and is marked by small circles at equal intervals of 5γ to 25γ distance from Q. The length of QD, or the average intensity of the difference between quiet and disturbed days, is 14.6γ.

The stereogram shows that the ends of the difference-vectors for the 14 years, though widely scattered, fall all near the line of the average vector QD or its extension. If each of the single vectors be resolved into two components, p parallel to and q perpendicular to QD, p varies from 7.5γ (for 1924, sunspot-number 17) and 7.9γ (for 1923, sunspot-number 6) to 23.2γ (for 1926, sunspot-number 64), while the average value of q, the average distance of the single points from the line QD, is only 1.5γ.

The greatest deviations from QD occur for 1919 ($p=17.9\gamma$, $q=5.3\gamma$) and 1921 ($p=15.2\gamma$, $q=3.1\gamma$). They are due to the influence of the two exceptionally heavy magnetic storms of August 11, 1919, and of May 13 to 15, 1921, both of which had, like the very greatest storms, features differing widely from normal storms.

In general, p is determined by magnetic or solar activity. Occasional divergence could be expected from the fact that, because of the "Nachstörung," the difference between a D-day and a Q-day is always greater if D follows Q than if D precedes Q. So not only the intensity of the disturbance, but also the relative arrangement in time of the D-days and Q-days will be of influence. This fact makes the value of p less satisfactory as a possible measure of magnetic activity, but does not invalidate the other conclusions drawn in this paper.

The average effect of disturbance on the magnetic field has been shown to be of partly external and partly internal origin.[6] Ad. Schmidt found that for each station the vector of the "Nachstörung" lies very nearly in the vertical plane which is parallel to the magnetic axis of the Earth, and that it points southward at an angle of 39° below the horizon for Potsdam. He investigated the residual of the "Nachstörung" which remains in the fluctuations of consecutive ordinary monthly means of the magnetic elements. The quite different data used in the present paper confirm Schmidt's conclusions, in so far as the vector QD lies nearly exactly in the vertical plane through QA drawn parallel to the magnetic axis of the Earth; in fact, the azimuth of QA (or of its horizontal projection QA') is 18°.9 east of south, while the azimuth of QD is 19°.5. Obviously, QD deviates systematically from the astronomic meridian and also from the magnetic meridian (indicated by $F'Q$ in the stereogram; the average declination is 7°.2 west, so that QF' points 7°.2 east of south).

The inclination of QD below the horizon is only 18° against 39°, as found by Schmidt from the fluctuations of consecutive monthly means. This seems to indicate that, in our case, the origin of QD is also mainly exterior, but that the interior part is relatively larger than in Schmidt's case.

In the upper part of the stereogram the results for the three seasons have been plotted in the same way but to half the scale of the lower

[6] Ad. Schmidt, Zs. Geophysik, **1**, 3-13 (1924/25).

part. The edge of each cube represents again 10γ. From left to right, the figures represent winter (southern solstice), equinoxes, and summer (northern solstice). Since each point represents the differences of only 20 D-days and 20 Q-days, the points are more widely scattered than in the lower picture; still they cluster about the central line which is drawn in the three diagrams in the direction of the mean *annual* difference QD. The largest deviations are again, for reasons given above, in the summers 1919 and 1921, which are represented by the lowest and the highest points in the diagram for $N. S.$ The point near Q_3 is only 2.1γ distant from that origin and represents the quiet summer of 1923.

The mean differences for each season are indicated by crosses. The lengths of these mean differences are 15.3γ for winter, 18.0γ for the equinoxes, and 10.3γ for summer. The higher value for the equinoxes was to be expected because the magnetic activity is then systematically higher. The horizontal azimuths of the average vectors are 23°, 20°, and 14° for the three seasons; their depressions below the horizon, 18°, 17°, and 20°, are remarkably consistent.

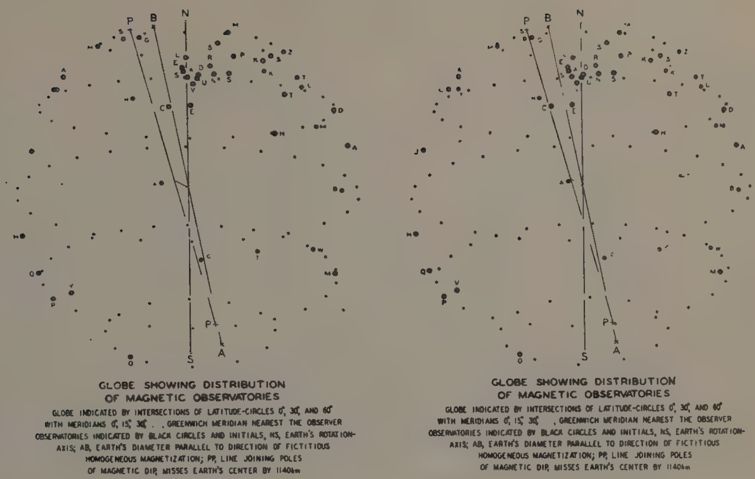
Further discussion must wait for the results of other observatories.

Stereogram 8—Stereogram 8 shows the secular variation of the magnetic field-vector at the intersections of the meridians 0°, 20°, 40°, etc., with the circles of latitude 60° N, 40° N, ... 40° S as derived for the epoch 1925 from the isoporic charts for D, H, and I constructed by H. W. Fisk,[7] and expressed as annual changes $\triangle X$, $\triangle Y$, and $\triangle Z$, of the north, east, and vertical (downward) component. The vectors with the components $\triangle X$, $\triangle Y$, $\triangle Z$ are represented in the stereogram as pointed cones. For instance, off the northeast coast of South America in longitude 40° west on the equator, $\triangle X = -21\gamma$, $\triangle Y = -72\gamma$, $\triangle Z = -99\gamma$, and the vector therefore points towards south, west, and upward. The scale can be judged from the distance between the meridians (15° apart) drawn on the chart, which corresponds in length to 61γ, and from the perpendicular lines drawn near the corners of the charts, which correspond in length to 100γ downward and 100γ upward or 200γ in all. The longest vector on the chart is found in 40° north and 40° west, where $\triangle X = +38\gamma$, $\triangle Y = +10\gamma$, $\triangle Z = -159\gamma$. This stereogram, because of its different construction, is better viewed at a shorter distance behind the lenses of the stereoscope than the others.

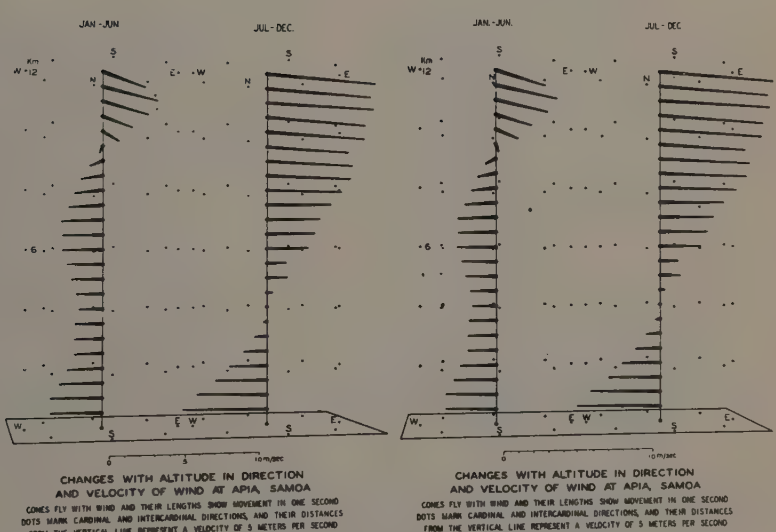
All our knowledge about the present secular variation is presented in this stereogram. A salient feature is the lack of uniformity or symmetry if the Earth's surface is regarded as a whole; but several regions of as much as one-tenth of the Earth's surface can be chosen where the secular variation seems to be dominated by some single process in the Earth's crust. In other words, the secular variation is not so much a planetary as a regional phenomenon. From this standpoint, the region of apparent increasing attraction at the west coast of South America is of interest in connection with A. Wegener's hypothesis of the drift of continents. Other features are the upward direction of the secular vector all over the Atlantic and the rapid change in the horizontal direction between 45° and 60° east longitude.

Stereogram 9—The relative positions of the magnetic axes of the Earth and the distribution of magnetic observatories are vividly shown

[7] Isopors and isoporic movements. Comptes-Rendus Assemblée de Stockholm, 1930, Internat. Geod. Geophys. Union, Sec. Terr. Mag. Electr., pp. 280-292, Paris, 1931. (The values of the secular variations for the three elements, their rectangular intensity-components, and total intensity upon which this stereogram are based will be printed in the next issue of this JOURNAL.—*Ed.*)



STEREOGRAM 9



STEREOGRAM 10

by stereogram 9. The globe is indicated by the intersections of the circles of latitude 0° and 30°, with the meridians 0°, 15°, 30°, etc., and of the circle of latitude 60° with the meridians 0°, 30°, etc. The Greenwich meridian appears nearest to the observer; the meridians 90° west and 90° east are at the left and right, respectively.

N and *S* are the geographical poles. *AB* is a line drawn through the center and parallel to that direction of a fictitious homogeneous magnetization of the Earth's body, which would best fit the observational data. This magnetization could also be assumed to have any radial distribution, concentric shells being magnetized in the direction *AB* with northern magnetism towards *A*; the extreme cases are that the magnetization is confined either to the outer crust or to the nucleus. The geographical coordinates are 78°.5 south, 111° east for *A*, and 78°.5 north, 291° east for *B*. *P* and *P* are the poles of magnetic dip (where the magnetic vector is vertical) in 70°.8 north, 264°.0 east and 71°.2 south, 150°.8 east. The line connecting the two poles of dip misses the Earth's center widely, its nearest point, the foot of the perpendicular from the center to *PP*, being situated 1140 km (more than 1/6 of the Earth's radius) from the center, towards a surface-point in about 0° latitude and 208° east longitude. This shows clearly the asymmetry in the Earth's magnetic field.

The 45 magnetic observatories are those which contribute to the list of international magnetic character-figures, and publish the results of continuous photographic records of the magnetic field. They are designated by the letters as shown in the following list in which they are arranged from north to south:

M, Matochin Schar (Novaya Zemlya)
G, Godhavn (Greenland)
S, Sodankyla (Finland)
L, Lerwick (Shetland Islands)
P, Pavlovsk (near Leningrad)
S, Sitka (Alaska)
S, Sverdlovsk (near Ekaterinburg)
R, Rude Skov (near Copenhagen)
K, Kasan
E, Eskdalemuir (Scotland)
M, Meanook (Canada)
S, Stonyhurst (Lancashire)
Z, Zouy (near Irkutsk)
N, Niemegk (near Potsdam)
S, Swider (near Warsaw)
D, De Bilt (near Utrecht)
A, Abinger (near Greenwich)
U, Uccle (near Brussels)
V, Val Joyeux (near Paris)
A, Agincourt (near Toronto)
T, Tiflis
E, Ebro (near Tortosa)
C, Coimbra (Portugal)
C, Cheltenham (Maryland)
K, Kakioka (near Tokyo)
T, Tsingtao
T, Tucson (Arizona)
L, Lukiapang (near Shanghai)
D, Dehra Dun (India)
H, Helwan (Egypt)
H, Honolulu
A, Alibag (near Bombay)
J, San Juan (Porto Rico)
M, Manila (Philippine Islands)
B, Batavia
H, Huancayo (Peru)
A, Apia (Samoa)
M, Mauritius
Q, La Quiaca (Argentina)
V, Vassouras (near Rio de Janeiro)
W, Watheroo (Western Australia)
P, Pilar (Argentina)
T, Toolangi (near Melbourne)
C, Christchurch (New Zealand)
O, Orcadas (South Orkneys)

The stereogram emphasizes some well-known features in the distribution of observatories. Thus we see the close net of stations in Europe and the fairly good distribution of observatories north of 30° north where there are 30 stations on one-fourth of the surface of the globe, while only 15 stations are scattered over the remaining three-fourths of the globe. A serious drawback in magnetic research is the

complete lack of observatories in the African sector south of 30° north between 45° west and 45° east—nearly one-fifth of the surface of the Earth! The importance of isolated stations such as Apia and Honolulu is also emphasized. The American sector contains a fairly good meridional chain of stations.

Stereogram 10—This stereogram visualizes the average upper-air currents at Apia, Samoa. Of 380 pilot-balloon flights made at Apia in the years 1923 to 1928, 286 reached an altitude of 5 km, 153 reached 10 km, and 94 reached 12 km. The average wind-components are given[8] for altitude-intervals of 0.5 km. Averages were formed by Mr. Thomson for all flights in the two half-years January to June and July to December. They are represented in the stereogram by cones, the lengths and directions of which correspond to the velocities and directions of the average horizontal air-current. In other words, each cone is the path of an air-particle which at a certain moment is on the central vertical line and is allowed to follow the average current for one second. The view is towards north from about 5-km height. In 0-, 2-, 4-, 6-, 8-, 10-, and 12-km heights a coronal of eight points is drawn at 5 meters' distance from the vertical line in the directions north, north-east, east, etc. So, for instance, the components of the air-movement per second at an altitude of 10 km averages 5.06 meters towards north and 1.75 meters towards east for January to June. In other words, the average wind blows with an intensity of 5.35 meters per second from about south-southwest.

Near the surface up to altitudes of 1 or 1.5 km the trade-wind flows from the southeastern quadrant throughout the year; above 10-km height, the counter-trades flow from the southwestern quadrant. Winds are generally stronger in the second half of the year. The westward flow of air extends from the surface to about 9 km in the first half-year, but only to 4 km in the second half-year. The change from the westward to the eastward movement is different in the two halves of the year. Thus with increasing height the vector swings, from January to June, from the westward movement through true northward at 9.3-km altitude with a velocity of 4.0 meters per second to the eastward movement, while from July to December the veering is through true southward at 4.3-km altitude, but with a velocity of only 0.6 meter per second.

In conclusion, I wish to thank C. C. Ennis for valuable help in the computations and drawings of the stereograms and for the computations of the secular-variation data, J. W. Green for skillful photographic work, A. J. McNish for scalings of storm-data for Watheroo records, and A. Thomson for the material represented in the last stereogram.

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[8] The data were taken from A. Thomson, Observations of upper-air currents at Apia, Western Samoa (second series). Dept. Sci. Indust. Res., Wellington, New Zealand (1929).

OBSERVATIONAL DATA				COMPUTATIONS STEREOGRAM-COORDINATES							
G.M.T.	ΔX	ΔY	ΔZ	$(1.1+ 4\Delta X/1000)$	f	$(3\Delta Y+20)$	$3\Delta Z$	$-65f$	$5y_1$	$5z$	$5y_2$
h m	γ	γ	γ			γ	γ		mm	mm	mm
1 00	-10.2	+ 5.1	- 5.1	1.0592	0.9441	+35.3	-15.3	-61.4	+33.3	-14.4	- 28.1
05	-17.4	+ 0.8	-12.4	1.0304	0.9705	+22.4	-37.2	-63.1	+21.7	-36.1	-41.4
07	-18.7	- 5.0	-21.5	1.0252	0.9754	+ 5.0	-64.5	-63.4	+ 4.9	-62.9	- 58.5
09	-27.8	-21.6	-25.6	0.9888	1.0113	-44.8	-76.8	-65.7	-45.3	-77.7	-111.0
10	-25.0	-21.8	-21.5	1.0000	1.0000	-45.4	-64 5	-65.0	-45.4	-64.5	-110.4
15	-12.9	+ 3.9	- 4.1	1.0484	0.9538	+31.7	-12.3	-62.0	+30.2	-11.7	- 31.8

SPECIMEN COMPUTATION

The time required for the computations can be considered shortened by systematizing them as shown, for example, in the specimen computations for stereogram 6 above. The data used are given in Figure *B*, being the deviations (ΔX, ΔY, ΔZ) of the north, east, and vertical (downward) components from their respective average values, expressed in γ (0.00001 C.G.S. unit), for the interval $1^h\ 00^m$ to $2^h\ 30^m$ G.M.T. First a suitable size and position for a three-dimensional model must be determined at a selected distance, say 750 mm. A cube orientated true north, east, and vertical, with an edge equivalent to 60γ, and centered at the origin of the deviations, will contain most of the points, since the values of ΔX, ΔY, and ΔZ do not exceed 38.4γ. With $2a=65$ mm, plate-distance $t=150$ mm, model-distance $d=750$ mm, formula (6) gives $(\eta'-\eta'')$ less than 260 mm. We therefore choose the edge of the cube in the model as 180 mm—thus $1\gamma=3$ mm. With $s=v=0$, magnification-factor of the drawing $m=5$, and ξ, η, and ζ expressed in millimeters, formulae (3) and (4) give $f=1/[(\xi/750)+1]$, $5y_1=(\eta+32.5)f$, $5z=\zeta f$, and $5\triangle y=65f$. It remains to choose the origin for the (ξ, η, ζ)-system. In order to obtain positive values for ξ, the origin must be close to the near face of the cube, but the exact position is at our discretion. We therefore choose it so that the final formulae will insure easy computation, and put $\xi=(3\triangle X+75)$, $\eta=(3\triangle Y-12.5)$, and $\zeta=3\triangle Z$; thus we obtain the final convenient formulae for computation as indicated above: $f=1/[1.1+(4\triangle X/1000)]$, $5y_1=(3\triangle Y+20)f$, $5z=3\triangle Zf$, $5\triangle y=-65f$. A table of reciprocals suffices to determine f; the multiplications are easily done with a computing-machine or a slide-rule; $5y_2=(-65f+y_1)$. $(5y_1, 5z)$ and $(5y_2, 5z)$ are the coordinates of the left and right component pictures in the drawings, y to the right, z downward. For photographing, the component pictures are placed side by side, so that the distance between the two origins of coordinates is exactly $2am=325$ mm; afterwards this distance is reduced photographically to 65 mm.

[Plate 5]

OBSERVATIONS OF THE AURORA AUSTRALIS, BYRD ANTARCTIC EXPEDITION, 1929*

By F. T. Davies[1]

Section I—Introduction

Observations of both the aurora borealis and australis indicate the existence of an auroral zone in each hemisphere and a belt of maximum activity within these zones. In the northern hemisphere this belt is situated some 23° from the point in which the axis of the uniform magnetic field of the Earth meets the surface. This point is not the magnetic pole, however, but is situated some hundreds of miles from it. Analysis of the auroral records of antarctic expeditions shows that a similar distribution of auroral frequency occurs in the southern hemisphere, though the data are insufficient to establish the position of the maximum activity-belt as accurately as is the case in the northern hemisphere.

Although the aurora australis is seen occasionally in the countries of the southern hemisphere—more frequently in Tasmania and New Zealand than in South America and South Africa—these countries are separated from the Antarctic Continent by wide stretches of ocean, little traversed by ships, so that only exceptionally widely spread auroral displays are observed to the north of the maximum frequency-belt in the antarctic.

Thus in the north the observations of polar expeditions are supplemented by considerable observational data in temperate latitudes, while our knowledge of the aurora australis is derived chiefly from the records of expeditions that have wintered on the Antarctic Continent. The following obtained auroral records: (1) Gerlache on the cruise of the *Belgica* in 1898; (2) Borchgrevink at Cape Adare in 1899; (3) Drygalski on Kaiser Wilhelm Land in 1902; (4) Scott at McMurdo Sound in 1902 and 1903; (5) Shackleton at McMurdo Sound in 1908; (6) Scott at McMurdo Sound in 1911 and 1912; (7) Priestley with second section of the Scott Expedition at Cape Adare in 1911; (8) Mawson at Cape Denison in 1912 and 1913; (9) Wild with second section of the Mawson Expedition at Queen Mary Land in 1912; (10) third section of the Mawson Expedition at Macquarie Island in 1912-15; and (11) Byrd at Little America in 1929. The number of auroral displays seen by the expeditions to the Graham Land region seems to have been very small. All the other stations, except Macquarie Island and on the cruise of the *Belgica*, were situated inside the probable maximum frequency-belt.

Of the records obtained during twelve winters on the Antarctic Continent half were observed by two men—those of 1899 at Cape Adare and of 1902 and 1903 at McMurdo Sound by L. C. Bernacchi and those of 1908 at McMurdo Sound and of 1912 and 1913 at Cape

* This article is an extended summary of the complete report and analysis of the report on the auroral observations of the Byrd Antarctic Expedition prepared by F. T. Davies, omitting the detailed log, tables, and discussion; the complete memoir, with tables, will be published in the proposed volume on the scientific results of the Expedition.—*Ed.*

[1] Physicist, Byrd Antarctic Expedition.

Denison by Sir Douglas Mawson. Major Priestley, who made the observations at Cape Adare in 1911, had also seen aurora at McMurdo Sound in 1908. All three of these observers had witnessed auroral displays in McMurdo Sound and also on the northern rim of the Continent, and agree that displays were brighter and more frequent at the latter stations. This agrees with the theoretical position of the maximum frequency-belt, which, in this sector of the antarctic, lies north of the coast. The direction in which aurora was most frequently observed at the north-coast stations was northerly. It seems probable that the Cape Adare station was the closest to the maximum belt. The records at Macquarie Island show most displays to the south. The base-station of the Byrd Expedition was well inside the maximum belt and, though further removed from it than the Cape Adare station, was much closer to it than the bases at McMurdo Sound.

The station at Little America was in latitude 78° 35′ south and longitude 163° 48′ west. The mean values of magnetic declination and inclination during the period of the auroral observations were, declination 106° 52′ east of north and inclination 82° 18′ south.

Section II—Procedure adopted and classification of aurora

Auroral observations were taken during the seven winter months of 1929—March to September. Nearly every member of the winter party cooperated in the work, which was under the direction of the physicist of the Expedition. A regular night-watch for auroral and meteorological observations was begun on April 3, 1929, and continued until the departure of the Expedition in February 1930. No aurora was seen during the summer months, October to February, as there were 24 hours of daylight during this period.

At first each man took turn at night-watch, but this procedure was not continued. For the sake of greater efficiency, seven men undertook the night-watch until the end of our stay at Little America. These were Q. A. Blackburn, A. H. Clark, E. P. Demas, W. C. Haines, H. T. Harrison, P. A. Siple, and F. T. Davies. The night-watchman was allowed the use of the library, which was heated by a small stove. Demas found that the quiet of the library during the night hours helped him to study, so he volunteered to take the night-watch for four months of the winter. His conscientiousness in observations and interest in the work contributed greatly to the completeness of the auroral record. One or other of the remainder of the group mentioned above took the evening observations from supper time to 10 p. m., and later on took turns at night-watch from September to February. The observations between breakfast and supper time were taken by F. T. Davies. All through the period of observation many members of the Expedition maintained an active interest in the work and made notes in the log-book.

Classification of aurora—The regular 24-hour watch begun on April 3 reported presence of aurora on 1,415 occasions at one-half hour or more apart. Each observation included the following information:

(*a*) *Time of observation*—One hundred and eightieth meridian time was maintained for the auroral record. Camp-time was changed twice during the period of observations, first to 165th west meridian time and later back to 180th meridian time. Notes of camp-time were made in the auroral log. One hundred and sixty-fifth west meridian time is very

nearly local mean time. The auroral results were tabulated for 180th mean time, one hour and five minutes less than local mean time. All graphs are drawn to 165th west meridian time. In summarizing results a display seen in the interval 15 minutes before or after a given half-hour was counted for the half-hour, even if no display was seen at the regular time of observation. The number so included was, however, very small compared with the total.

(*b*) *Classification used in recording form of aurora*—In the auroral classification adopted—very similar to that adopted by previous antarctic expeditions—six forms were included and classified under five heads, namely:

(1) *Glow*—A patch of light of indistinct limits and always a quiet display.

(2) *Arch*—Arcs, arches, or bands are essentially of the quiet type of display without ray-structure.

(3) *Curtains*—Rapidly moving forms differing from arches in the wave-like appearance of their lower rims and in their varying intensity and movement—nearly always with ray-structure.

(4) *Rays and streamers*—Rays, as the name suggests, are thin lines of light; bundles of rays were frequently seen shooting through curtains. An isolated ray or pencil of rays was termed a streamer. Ray and streamer were so often found as interchangeable terms in the record that in summarizing results they have been classed together. They were nearly always seen in vertical distribution and very frequently in rapid movement.

(5) *Corona*—The corona is a phenomenon produced by a radial distribution of rays, streamers, or curtains from some small area in the sky which is dark. The center from which the display seems to diverge was called the radiation-point, and was nearly always at the zenith or very close to the zenith. No instance of a flaming corona was seen, but the coronal structure as above described was frequent.

Curtains, rays, streamers, and corona are associated in a group characterized by Störmer[2] as having ray-structure, while the group comprising glows, arches, or bands has no ray-structure. Sverdrup[3] distinguished these groups as "moving" and "quiet" aurora, because rapid movement is a characteristic of the ray-structure group.

(*c*) *Intensity*—The intensity of a display was estimated by the observer on an arbitrary scale 0-IV thus: 0, none; I, faint; II, moderate; III, bright; and IV, brilliant. This is the same scale as has been used by Sverdrup[3] on the *Maud* Expedition in the arctic and also on other antarctic expeditions. As intensity is an eye-estimate only, it is not easy to compare intensity-records of different expeditions. That is one reason why observations taken by the same observer in different localities are of greater value.

There is no doubt that the intensity of displays seen at Cape Adare

[2] Photographic atlas of auroral forms and scheme for visual observations of aurorae. Published by Internat. Geod. Geophys. Union, Oslo (1930).

[3] Res. Dept. Terr. Mag., 6, 462 (1927).

in a year of low sunspot-numbers (1908) was greater than that at Little America in a year of high sunspot-numbers. As the latter base is considerably nearer the maximum activity-belt than McMurdo Sound, one would expect the average intensity of aurora to be greater at Little America. This does not seem to have been the case, for comparison of records shows intensity about the same. This may be due to a difference in the respective standards of intensity adopted.

(*d*) *Direction*—The limits of direction in which aurora was seen were noted in terms of true directions, N, NNE, NE, etc.

(*e*) *Altitude*—The limits of altitude between which a display was observed were recorded. In the case of arches and curtains, the highest points corresponded to the highest altitudes marked at the time. Aurora passing through the zenith was marked Z. Angles were read from the horizon in the directions marked under the direction-record. For example, the entry for an arch from 5° north through the zenith to 20° above the horizon in the south was "A. N-Z-S. 5-90-20."

(*f*) *Color*—The aurora was usually of a whitish color, often with a greenish tinge. The most frequent entries for color in the log were *w* for white, *wg* for whitish-green, or *gw* for greenish-white. Yellow, orange, red, and violet colors were occasionally seen and marked by the first letter of the color, as were also pink and blue, which were noted at times.

Throughout the observations color was associated with increased intensity and movement of a display. Red was seen along the lower rims of curtains and sometimes arches, but pink, green, and violet were only seen in bright rapidly moving displays.

(*g*) *Wind and clouds*—Two columns in the record were kept for wind-direction and amount of sky covered by clouds. The latter was estimated in tenths of the area of the sky.

(*h*) *Remarks*—The last column in the record was for observer's remarks. Fuller details of aurora seen, mention of kind of clouds and whether stars were visible through them, presence of moonlight and position of moon, solar and lunar coronas, etc., were noted.

Section III—Auroral log

The first aurora reported during the year 1929 was seen by the geological party in King Edward Land, some 130 miles east of Little America. This was on the night of March 16 to 17 at about $01^{h}\ 00^{m}$ 180th meridian time. A bright curtain was seen in an ESE direction. There was considerable daylight at the time.

During March 22 to 23 from 23:00 to 01:00, the party on trail 30 miles east of camp saw an arch of moderate intensity in the northeast. There was moonlight and considerable daylight at the time.

On March 30 between 20:00 and 21:00 a faint glow was seen at base-station.

On March 31 between 20:00 and 21:00 a curtain of moderate intensity was seen from N to E between 10° and 50°. It was of greenish-white color and was brightest in NE at 30°. There was moonlight at the time.

No aurora was seen during the evenings of April 1 and 2. As before stated, the regular night-watch began April 3, 1929, and was continued to October 1, 1929.

This voluminous and detailed auroral log will be published in the

volume of scientific results of the Expedition. The following detailed notes on some rapid movements of aurora on May 13, 15, and 30, 1929 may meanwhile be of particular interest:

May 13, 1929:

14:00—Arc, II, NE-SE, at 5°-15°-5°; rapidly developed into curtains which moved westward.

14:05—Curtains, N-*Z*-SE, 5°-90°-5°—brilliant, rapidly pulsating; colors, red, orange, yellow, and green.

14:07—Brightest at *Z*.

14:15—Wide band of curtains N-*Z*-S, 90 degrees wide at *Z*, narrowing to a long, snaky curtain towards S. Colors, pink, green, and yellow. Daylight in northern sky.

14:23—Movement rapid since 14:15. Wide band curtains N-*Z*-S from 70° above east horizon to 60° above west horizon. Band narrower toward S. Central curtain brightest, running through *Z*. This curtain made an almost complete turning movement. The southern end moved east and nearer *Z*, the northern end moving west, but not as much movement as southern end. Inside three minutes, at mean time 14:19, this curtain had swung round to a position 70° above NW horizon to 30° above ENE. Its maximum altitude was in the north at 80°. This was the time of greatest brilliancy. Pink, green, yellow colors seen and rays darting through curtains continuously.

14:33—Bright curtains NNE towards S, one sweeping from NNE towards *Z*, turning N, then NW at altitude 60° and sweeping back to S. Very wavy curtain; colors, pink, green, and yellow. Other curtains from NE towards *Z* and E towards S. In NE and S curtains of greenish-yellow color and quieter than in other parts of sky. Twilight in northern sky, but curtains were visible down to 5° altitude in the NNE, where even the stars were but faintly visible against the light background of the sky. The greatest activity and brilliance since 14:05 occurred at this time. The whole sky from 30° altitude in E through *Z* to 80° altitude west was filled with curtains. Intensity varying, but display less brilliant than at 14:05. General trend now from E towards the much brighter curtain running N-*Z*-S.

14:40—Series of curtains NE towards *Z* and then E, ending at 15° in SE. Maximum altitude 70°. Pink color still showing at lower tips of rays, but movement considerably less.

14:42—Curtains less bright, II, and nearer E, running N towards 70° E towards SE. Brightest in NE, whereas earlier in display brightest part was SE. The curtains first formed from the bright SE part of the arc. Very faint glow overhead.

14:48—Brightest part of curtain more like an arch, intensity II. Brightest at lower edge and steady, forming smooth curve from NE up to altitude 40°, then back to E, ending in a glow at altitude 5°. Three fainter bands ran from NE towards E at a lower altitude. Color yellowish-white. Weather clear all through display, stars visible, west wind, twilight in northern sky, with reddish-brown sunset tinge on N horizon.

14:55—Position same as when last described, but intensity increasing. The arch seen at 14:48 split into two well-defined and rapidly moving curtains from NE towards E, which were tinged with pink. Intensity uniform. Lower band steadier and smooth-edged, running NE-SE, 5°-10°-5°.

15:00—Display brighter, III, northern ends moving up sky and towards E, while SE ends remain steadier. Sweeping movement of northern ends in westerly direction, so that curtains all showed a bend towards the west. Curtains in E sky with greatest altitude, at bend, of 40°. Streamers running towards *Z*.

15:05—Very broad and ill-defined curtain from 5° E towards NE towards E towards NE and then E at 40° to a much more sharply defined curtain in SE. Two wide, snaky waves in above. Brightest in NE, but vague in outline. Another curtain appearing in SE running toward *Z*, but only from 5° to 15°. Intensity II.

15:10—Same general position, but curtains up to 45° in ENE, nearer horizon in SE and touching horizon in S. Little change in intensity, which is uniform II. Color greenish-white.

15:15—Curtain NNE towards SE. Brightest in NE and also widest part of band in NE, extending up to 45° altitude. Narrows towards SE. Faint glow on S horizon.

15:20—Double curtain from NNE towards E, one part running to SE at a maximum altitude of 25°, the other part running from E back to NE and then up into E sky, fading away at about 70° altitude. Brightest in NE. Greatest movement in NE and E. Glow in S more pronounced.

15:25—Curtains moving nearer Z, but upper part faded. Lower part rising. Curtain from N towards SE. Glow from S spread around to SE.

15:30—Curtains lifted, now running N towards E, maximum altitude 60° in NE. Glow E towards S with faint streamers rising from S and also from E towards Z.

15:35—Bands in S at 5° and 15°, extending slowly to SE. Curtains N towards E and E towards SE, the latter near the horizon. Highest point of curtain in NNE towards E at 45°.

15:40—Faint band N towards E towards S between 5° and 10° altitude. Brightest, though intensity only I, in S. Curtain of intensity II from N towards E, altitude 5°-40°.

15:45—Bands N towards E broad and faint from 5°-30°. Highest in E at 40°. Sharp band, II, E towards SE at 5° altitude. Faint broad glow SE towards S from 0°-15°.

15:50—Faint band NNE-E at 20°. Sharper band E-SE with broad patches at each end of intensity II. Glow in SSE at 10°.

15:55—Faint band NNE towards E, 5°-20°. Brightest in E at 30°. Sharper and brighter band SE towards S at 10°.

16:00—Almost same. Bands NNE-S, 5°-25°. Brightest in SE. Intensity I.

16:15—Display in NE sky. Curtain, intensity I to II, from NE towards ESE, diffused.

16:30—Bands N-Z-ESE, 5°-90°-5°, pulsating slightly. Intensity III.

16:45—Curtain, III, NNE towards E, beginning on NE horizon, sweeping E, thence wide fold to westward, reaching a point at 45° in N, then back to E horizon.

17:00—Broad series curtains NNE horizon towards ENE, then towards W to altitude 60° in N, and returning at altitude 70° towards E, ending at 20° ESE. Intensity II to III. Glow in SE.

From 17:00 notes were made half hourly. Display continued to 19:30, faded away entirely and reappeared at 21:00, intensity increasing to a bright display at about 03:00 on May 14.

In the above notes, when the curtains faded and became diffused they were termed bands, but movement was more rapid in these bands than is usually associated with arches. The turning movement of a curtain at 14:19, from N towards S to NW towards ENE in a period of three minutes, was the only occasion during the winter when such a phenomenon was seen. Movement of the ends of curtains, particularly southern ends of north towards south curtains moving into east sky, was often noticed. These formed large horseshoe-curtains which sometimes twisted into a spiral. The bend of horseshoe-curtains was toward the west.

May 15, 1929:

15:30—Low curtain at about 30° altitude from S-W-N-NE. Also huge spiral curtain from north horizon towards NE at lower altitude than first curtain, and then running through Z towards W, turning NW, and curving inwards to NE, and spiraling into center. This spiral filled the sky from NW towards NE. Intensity changing rapidly. Curtain first wound up into a spiral and then uncoiled itself, growing fainter and at the same time moving bodily eastwards. Rays ran from curtains towards Z, forming a corona. Glow and streamers in all parts of sky, but these not as bright as the curtains. The radiation-point of the corona was slightly north of zenith.

15:45—Glows, streamers, curtains, and coronas in all parts of sky, though not as bright. Intensity now II-I. Three well-defined curtains N-W-S, with streamers running towards *Z*. With the exception of the western horizon, all the sky was filled with very diffused curtains and streamers.
16:00—Curtain N towards NE up to 70° W towards NW-N, spiral form. Curtain NE towards E towards *Z* towards S. Brightest in S. Glow in east sky from NW towards S.
16:30—Curtain NW towards E, 15°-40°, intensity II. Curtain S towards SE towards *Z*, faint. Glow in east sky. Faint streamers towards *Z*.

May 30, 1929:
10:00—A rapid movement was observed at 10:00. Streamers in N at 45° and glow in S at 30°. In an interval of two minutes a rapid change took place. Curtains, intensity I to II, formed between the streamer and glow, running N-*Z*-S. Curtain brightest in N. The curtains would probably have appeared brighter but for the presence of the moon in the NE. These two curtains moved westward rapidly, pivoting about their northern ends, which remained in the same place. After two minutes the curtains ran N-W-SW, intensity II in N and I in W and S. Altitude 30° N towards 80° W-20° S. Half moon and bright lunar corona in NE.
10:30—Four arches of intensity I ran N-*Z*-SE, 20°-90°-20°. Maximum width of whole band (four arches) about 30° at *Z*. Intensity decreased and whole band moved eastward slowly, motion most marked in southern ends. As southern ends moved towards SE they curved back a little.
10:45—Aurora disappeared. Distinctive feature was westward movement while display developed and eastward as it faded away.

At times there were quiet, persistent displays. Thus there was an exceptionally quiet and persistent arch during forenoon and early afternoon of May 18, 1929. A low arch, faint intensity, appeared in the east sky at 08:30, 180th meridian time. Its direction was NE-SE, altitude about 15°. Disappearing between 09:00 and 11:30, it reappeared at the latter hour and as a double arch maintained practically the same position and intensity until 14:00. Its direction changed to N-SE between 14:00 and 15:00 and altitude increased to a maximum of 40° at 14:30. The display was a little brighter and took on the appearance of a curtain. At 15:30 this faded and receded into the NE as a glow. No display was visible at 16:00. This change from a quiet display, continuing at the same position and intensity for several hours and then increasing in activity and altitude and rapidly fading, is typical of the development of many of the displays seen, though in this case the length of time during which the arch maintained its position was exceptional.

Quite often in the auroral log a display which is described as an arch when low in the sky is denoted as a curtain when it rises in altitude and increases in intensity. It is more than probable that the increase in intensity is due to the display being nearer. Since in many of these cases of change from "arch" to "curtain" the phenomenon is really continuous and in the same direction, it seems that these terms are being applied to the same thing. The movement noticeable in a curtain closer to the base is not easily discernible at a great distance.

Auroral log aboard "City of New York" on return to New Zealand—During the return voyage in March, 1930, to New Zealand aurora was seen on three nights when the *City of New York* was on a northerly course in longitude about 168° 26′ east. On March 2 in latitude approximately 65° 09′ south, aurora was seen between 21:00 and 23:00 (local mean time), the entry at 21:00 being S, I, SW, 50°, when it was quite light and cloudy. Between 21:00 and 23:00 a brighter aurora was reported in N, E, and W.

On March 3 a faint aurora was reported between 20:00 and 24:00

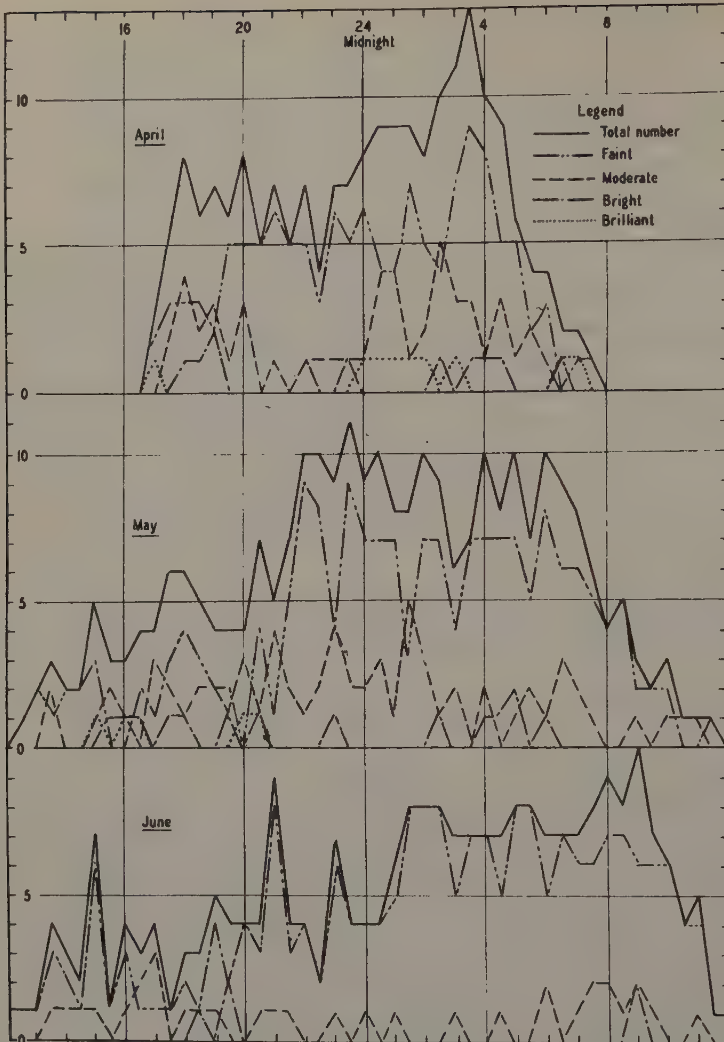


Fig. 1—Diurnal change monthly totals auroral displays of different intensities observed at half-hour periods, Little America, 1929 (165th west meridian time)

(local mean time). The ship was approximately in latitude 62° 16′ south at 22:00.

On March 4 the night was cloudy. At 19:45 (local mean time) two faint bands in NW were reported.

No other displays were reported during the voyage, though each watch was requested to keep notes of any displays.

Section IV—Discussion of Results

Diurnal variation in intensity of aurora—The number of displays of different intensities observed at the half-hour periods are illustrated for each month in the graphs of Figure 1.

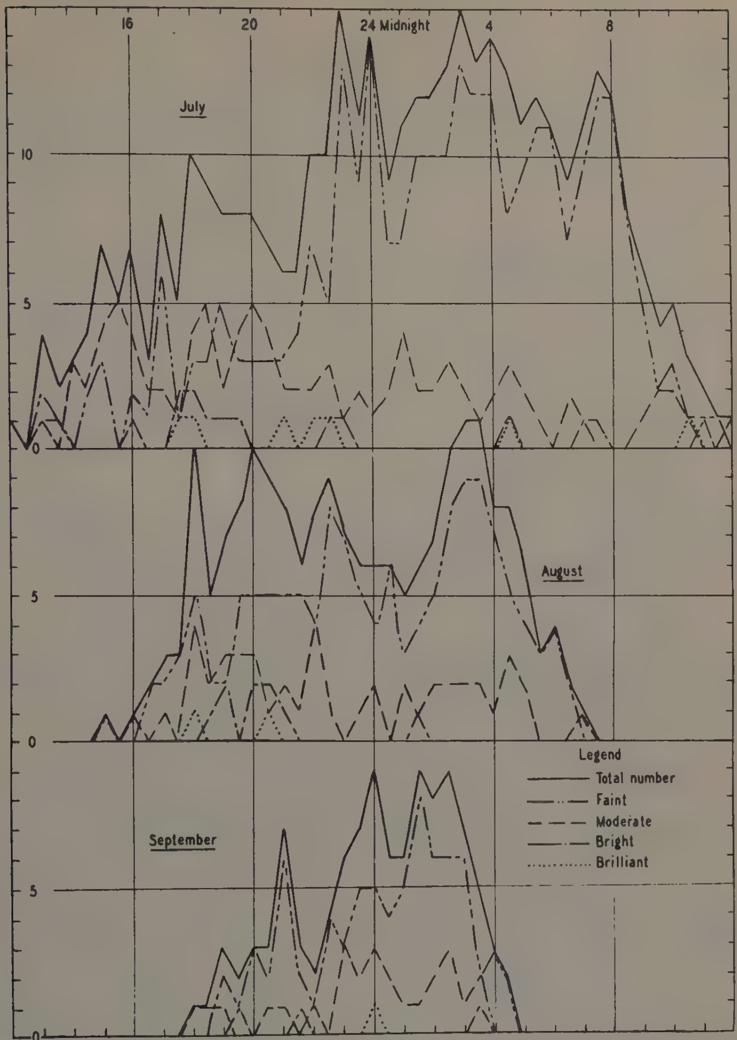


FIG. 1—Continued

Figure 2 shows the total values for the six months April to September. It is seen that the large proportion of displays are of faint intensity and that their number increases rapidly from 19^h, reaching a maximum at 3^h to 4^h and falling off rapidly towards morning. The brighter displays are more evenly distributed, with a maximum at 18^h to 19^h. There is a decrease in the number of displays of from moderate to brilliant intensity in the interval 20^h to $23^h.5$, during which faint displays become increasingly more numerous. An increase in number of brighter displays occurs after midnight until about $4^h.5$, when the number falls off towards morning. The curve of total displays seen has a maximum at $2^h.5$ and falls off sharply through the morning hours. A sharp rise in

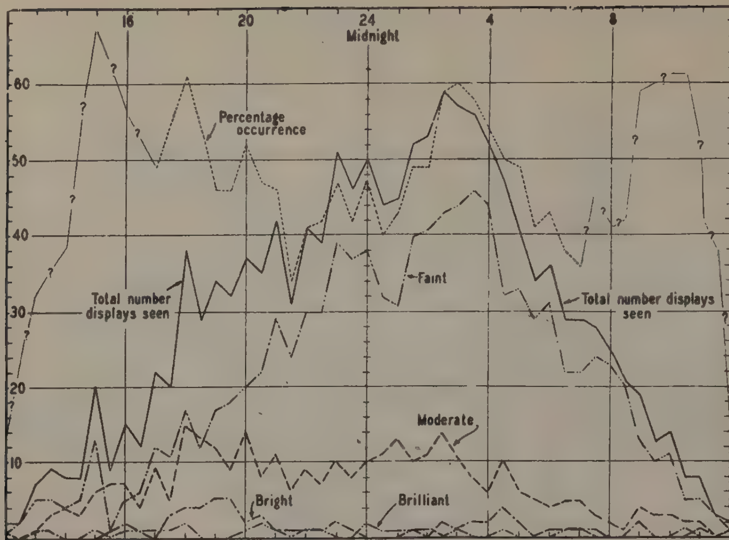


Fig. 2—Number auroral displays seen and diurnal percentage-occurrence, Little America, April to September, 1929 (165th west meridian time)

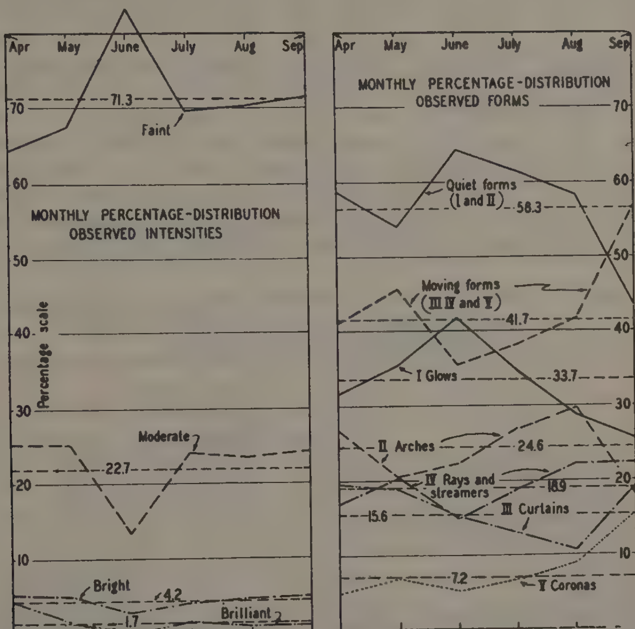
number of displays occurs at 18^h, at which time the proportion of brighter displays is greater than at any hour of the night. The afternoon hours show a high proportion of displays of moderate intensity. The lower values during the day from 6^h to 18^h are due in part to the amount of daylight at the beginning and end of the auroral period.

Intensity-distribution—Figure 3 shows the percentage-proportion of displays of different intensities to the total number seen during each

Table 1—*Summary showing number and intensity of auroral displays at Little America 1929, Cape Evans 1911 and 1912, and Cape Adare 1911*

Station	Year	Intensity-scale	No.		Per cent total	
Little America	1929	"Faint"	1,011		71.5	
		"Moderate"	320		22.6	
		"Bright"	60		4.2	
		"Brilliant"	24		1.7	
		Total	1,415		100.0	
			1911	1912	1911	1912
Cape Evans	1911 and 1912	"Very faint"	28	4	6	2
		"Faint"	220	74	48	47
		"Moderate" to "fairly bright"	169	67	36	42
		"Very bright" to "bright"	46	14	10	9
		Total	463	159	100	100
Cape Adare	1911	"Faint"	66		17	
		"Average or below"	170		43	
		"Average or above"	93		23	
		"Bright"	69		17	
		Total	398		100	

month. It is seen that the proportion of faint displays increases from April to September, June having an exceptionally high proportion. The proportion of bright and brilliant displays is highest in April. The mean intensities for each month show highest value for April and, with the exception of a very low value for June, a decrease through the period April to September.



FIGS. 3 and 6—Percentage-distribution observed auroral intensities and forms to total number during each month, Little America, 1929

The number and intensity of displays recorded during the six-month period at Little America are summarized in Table 1. It is seen that the number of displays increases rapidly as the intensity diminishes. This distribution is interesting in comparison with the data of the Scott Expedition of 1911-12, which C. S. Wright,[4] reporting on the work of the British Antarctic Expedition 1910-13, summarizes. These are also shown in Table 1. The data for the three stations are shown graphically in Figure 4.

Comparison is difficult because of the different standards of intensity. It is seen, however, that the three records of the British Antarctic Expedition show greater proportions of displays in the second and third groups

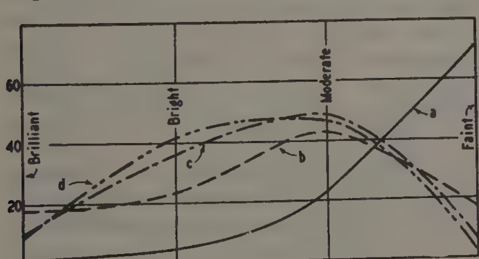


FIG. 4—Percentage-relation of number and intensity auroral displays: (*a*) Little America, 1929; (*b*) Cape Adare, 1911; (*c*) Cape Evans, 1911; (*d*) Cape Evans, 1912

[4] Observations on the aurora. British (*Terra Nova*) Antarctic Expedition, 1910-1913. London, Harrison and Sons, Ltd. (1921).

than in the first and fourth. In discussing these data C. S. Wright[1] says: "It would seem, therefore, that the frequent occurrence of 'no aurora' is probably a real effect, corresponding to a total absence of aurora, rather than to occasions when the aurora was present, but of such low intensity as to be invisible to the eye. If this were not the case, one would, I think, expect to find a much higher proportion of aurora in the 'very-faint' class." At first sight the data at Little America for 1929 suggest the opposite conclusion. Since there are progressively greater numbers recorded as intensity diminishes, one might assume that if means were devised sensitive enough to detect aurora under unfavorable light-conditions, aurora would probably be found during the periods when eye-observations record "no aurora." It seems probable, however, that in the intensity-scale used at Little America the classes brilliant (IV) and bright (III) correspond to the "bright" class of the earlier records, and the class faint (I) to the sum of "faint" and "very faint." The data of Table 1 are rearranged in this way in Table 2.

ABLE 2—*Summary percentages auroral displays at Cape Adare, Cape Evans, and Little America on basis approximately equivalent intensity-scales*

Station	Percentage		
	Bright	Moderate	Faint
Cape Evans, 1911	10	36	54
Cape Evans, 1912	9	42	49
Cape Adare, 1911	17	23	60
Little America, 1929	6	23	71

It is possible that, had we divided the 71 per cent of faint displays into "faint" and "very faint," the results at Little America might have agreed better with those of 1911-12 at Cape Evans. Here is an example of the difficulty of comparison of intensity-records when the measure of intensity is only an eye-estimate. The intensity of display at Little America was estimated in comparison with that of aurora borealis seen by a number of the winter party. It was generally agreed that the number of displays approaching in brilliance the brightest we had seen in the north was very few. A spectroscopic standard of intensity is necessary. In this connection it may be remarked that the appearance of colors other than the usual white, whitish-green, or whitish-yellow was associated with increased intensity. Red, orange-yellow, green, pink, and violet were seen—red was usually seen in quiet and in rapidly moving displays, but the violet and pink colors were seen only in rapidly moving displays.

Daily variation in type of aurora—Totals of the number of different forms of aurora seen in the half-hourly observations are illustrated for each month in Figure 5, showing the total values for the six months April to September.

Distinctive features are the large number of glows, usually of low intensity, in the middle of the night; the large number of arches and curtains at 18^h to 19^h; increasing numbers of arches from a low value at 20^h to a maximum at $3^h.5$ with a rapid decrease afterwards; low

number of curtains from $21^h.5$ to $0^h.5$ and then a sharp increase to a maximum at $2^h.5$ with a rapid decrease to a low value at 6^h, followed by an increase in the forenoon hours; rays, streamers, and corona, few before midnight, but much more numerous after midnight. The generally low values around noon are in part due to daylight influence. Figure 5(a) shows the numbers of "moving" and "quiet" forms. For the greater part of the day, noon to 2^h in the morning, quiet forms

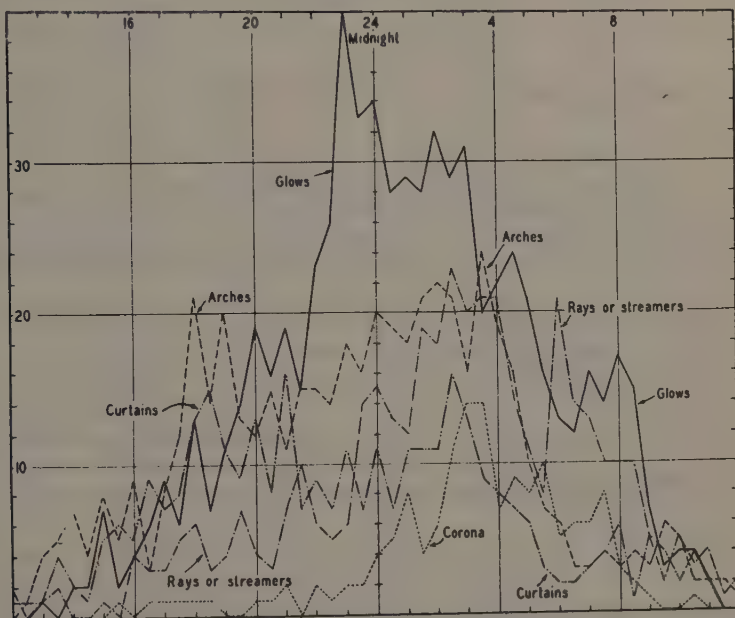


FIG. 5—Total numbers auroral forms seen in half-hourly observations, Little America, April to September, 1929

predominate; from 3^h until noon the proportion is nearly the same. The quiet forms are fairly equally distributed about midnight, but the number of moving forms before midnight is low compared with the number on the morning side of midnight.

Monthly variation in type of aurora—The percentage-proportion of aurora of different types or forms during each month is shown graphically in Figure 6.

The proportion of glows is highest in June, the month of lowest mean intensity; it falls off rapidly during the later months. The arch-form shows a maximum in August, falling to a minimum in September. The number of curtains falls from April to August and increases in September. The most definite trend, however, is in the proportion of corona which roughly parallels the curve for rays and streamers, and indicates a steady increase through the period April to September. The number of quiet displays is greater than the number of moving displays in all months except September. The proportion of quiet displays for the whole year is 58 per cent; moving displays, 42 per cent.

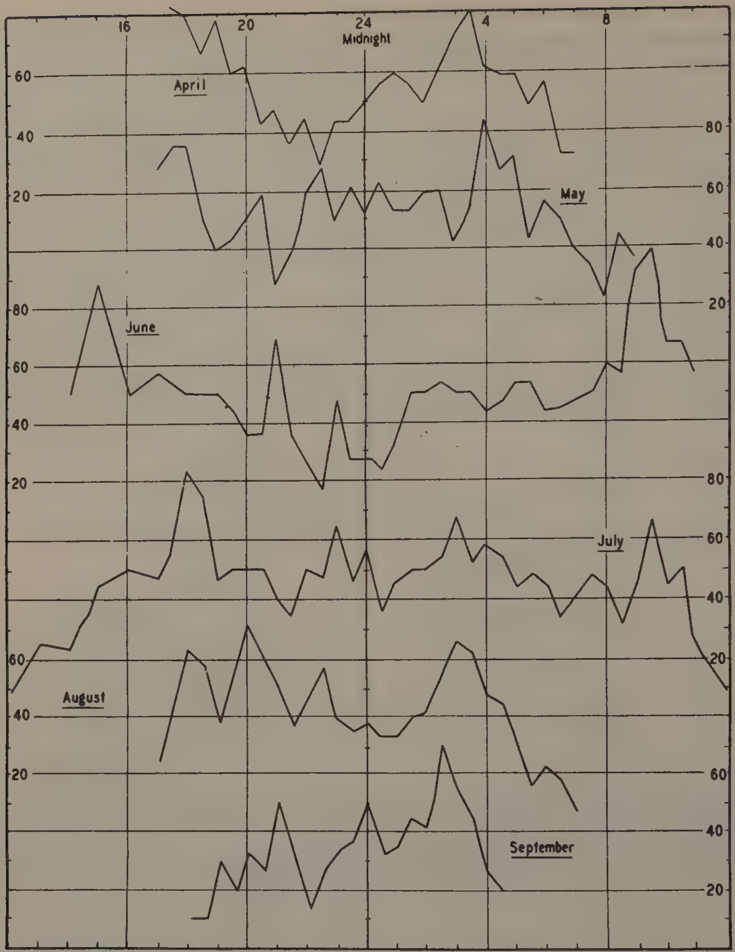
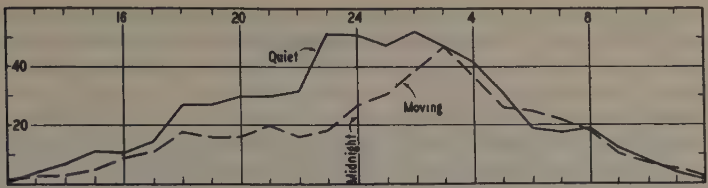


FIG. 7—Diurnal change for each month showing number auroral displays seen expressed as percentage of the number that could possibly have been seen, Little America, 1929 (165th west meridian time)

DISCUSSION

Auroral frequency—The possibility of seeing aurora, if existent, depends on the amount of daylight or moonlight, the extent of cloudiness, and the thickness of cloud. To determine a true occurrence or frequency-curve, it is necessary to decide under what conditions aurora can be seen.

In this discussion, all hours between dusk and daybreak at which observations were taken and for which the amount of cloud was 0.6 or less, are taken as times when it was possible to see aurora. The value 0.6 of cloud was chosen because aurora was frequently seen when the sky was clouded to this extent. There is no doubt that, on occasion, faint aurora of small extent would be obscured by as much as 0.4 cloud,



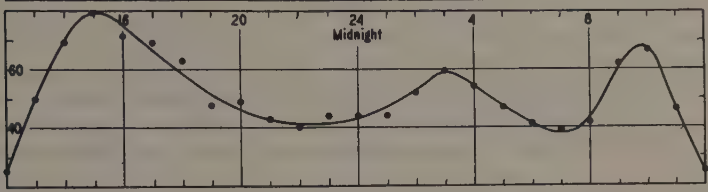


FIG. 5a—Smoothed mean hourly numbers of aurora, "quiet" and "moving" forms, Little America, April to September, 1929 (165th west meridian time)

FIG. 7*a*—Mean diurnal change, smoothed hourly values expressed as percentages as in Figure 7, Little America, April to September, 1929 (165th west meridian time)

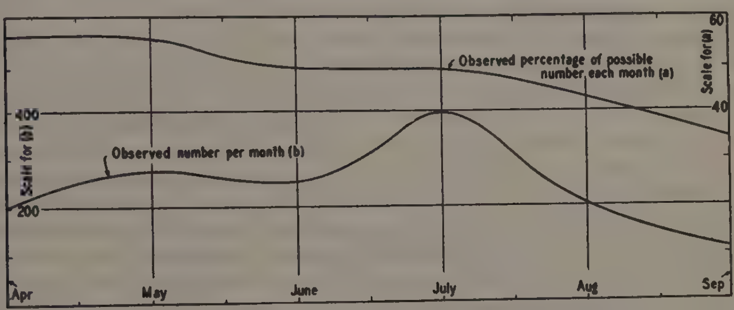


FIG. 8—Number of auroral displays seen expressed as percentages (*a*) of the number that could possibly have been seen during each month, and (*b*) of the total number, Little America, 1929

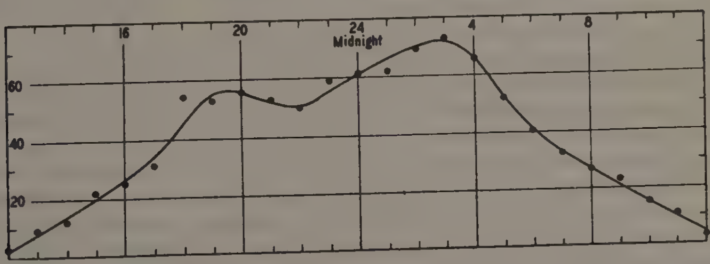


FIG. 9—Smoothed hourly totals of auroral character-numbers, Little America, April to September, 1929 (165th west meridian time)

but aurora was actually seen when cloudiness was 0.8 or 0.9. This is because during the winter the clouds were often of thin cirrus type, through which aurora and stars were visible. No allowance is made for moonlight, as oftentimes aurora was seen in the presence of bright moonlight. It is probable that the estimate of the number of hours at

which aurora could be seen is higher than it should be, due to neglect of the moonlight-factor. It was thought better not to attempt to correct for it, but to take account of moonlight-periods in subsequent study of the data.

All days from the beginning of the night-watch to September 26, when aurora was last seen, were considered as possible auroral days, subject to the above limitations. The interval from March 16, when aurora was first seen, to midwinter, 96 days, was the same as that from midwinter to September 26. This period of rather less than 200 days is approximately the limit of days on which aurora can be seen during the year at Little America. The ratio of the number of observations of aurora to the estimated number of possible observations during the same interval, expressed as a percentage, is taken as the auroral frequency.

Diurnal change—The diurnal frequency for each month is illustrated in Figure 7. Five months show a high frequency at 3 to 4 o'clock in the morning; all show a low value between 21^h and 23^h; four months have a high frequency at 18^h; a high value at 15^h occurs in June; in the two months June and July—the darkest months—a high frequency-value occurs between 9 and 10 o'clock in the morning.

The mean values for the whole six-month period are shown in Figure 2, the broken lines indicating doubtful values because of fewer data during the middle of the day. Figure 7(a) shows the smoothed values for full hours only, the broken curve indicating doubtful values during the day. There are two marked high values during the dark hours, at 18^h and 3^h, with a low frequency during the hours before midnight. These features are indicated in the individual monthly curves. A probable increase in auroral frequency occurs at 15^h and 10^h, though whether the frequency at these times is actually greater than at 3^h is very doubtful. The smoothed values, doubtful ones included, indicate three maxima in the diurnal frequency at 3^h, 10^h, and 15^h, of which only the one at 3^h is certain. Low values of frequency occur at 7^h, 12^h, and 22^h, the one at 12^h being doubtful.

In connection with these times, it may be noted that magnetic midnight occurs at 21^h and magnetic noon at 9^h (magnetic midnight occurs when the station, magnetic axis, and the Sun are in line).

Auroral frequency through months—Figure 8 shows for each month (*a*) the ratio of observed displays to the total for the whole period, and (*b*) the monthly frequency—that is, the ratio of observed displays to the total possible displays in each month. Curve (*a*) is influenced by daylight, cloud, etc., but (*b*) is corrected as far as possible for these factors. The frequency is seen to decrease from April to September. This seems to be a real effect. Whether this decrease in frequency is part of an annual change during which there occur a maximum and a minimum, or whether it is a change proceeding through a term of years, for example, the sunspot-cycle, it is impossible to say without having available several years of auroral observations.

Auroral character-number—The intensity of a display at a given time was chosen as an estimate of the activity of aurora for the half-hourly period centering on the time of observation. The sum of the intensities recorded in a day is taken as the character-number for that day. Thus the character-number includes two factors—intensity and duration of display. For example, if a brilliant aurora were seen at one observation

only, it would contribute 4 to the character-number, whereas a faint display seen on four occasions would also add $4 \times 1 = 4$ to the character-number for the day.

This measure of auroral character differs from others that have been adopted. H. U. Sverdrup[3] (*Maud* Expedition results) added to the intensity-figure at a given hour the number of different forms of aurora seen. Another method has been to allot three character-numbers only to different days, 0 for no aurora, 1 for aurora without ray-structure, and 2 for aurora with ray-structure. It is difficult to decide upon an entirely satisfactory estimate of auroral character. Such factors as the extent of sky covered by an aurora, its rapidity of movement, and perhaps color might be included in estimating auroral character. It is felt that the difficulty of giving the right significance to factors other than intensity and duration of a display is too great.

Diurnal variation in auroral character-number—The smoothed mean daily values of auroral character-number for each half-hour for each month and also for the whole period are plotted in Figure 9. Greatest activity occurs at 3^h and least activity occurs at noon. These figures are uncorrected for cloud- and light-conditions. They represent actually what was observed. A secondary maximum is evidenced between 18^h and 20^h, followed by a lull in activity at 22^h. The rise is steady from 22^h until 3^h, after which the curve falls off rapidly. The fall from maximum to minimum in nine hours is more rapid than the rise in fifteen hours. The time of greatest change is from 17^h to 18^h.

Auroral and magnetic character-numbers—The auroral character-numbers for Greenwich days—that is, noon to noon at 180th meridian time—were compiled for comparison with the international magnetic character-numbers given for Greenwich days. A comparison of different days in auroral character is best accomplished when noon-to-noon values are taken, corresponding to minimum values of auroral character. The relationship between increased magnetic activity in temperate latitudes and auroral activity is illustrated in Figure 10.

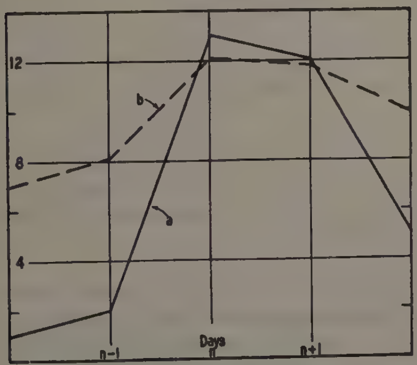


FIG. 10—Mean auroral character-numbers (*b*) and times auroral maxima fell on or near magnetic-activity maxima (*a*), Little America, April to September 1929

Dates of high mean magnetic character-numbers were taken from the International Tables. Auroral character-numbers were tabulated for these dates (*n*) and for two days before and afterwards. Mean values of auroral character-number were computed and plotted in curve (*b*) of Figure 10. It is seen that the mean auroral character-number rises on dates of high magnetic number, maintains a high value on the following day, and then falls off. The rise is more rapid than the subsequent fall in auroral activity. Of 35 maxima in magnetic character-number 13 were found to occur on the same day as an auroral character-number maximum. On 12 occasions an auroral maximum occurred one day after a magnetic maximum; on five occasions an auroral maximum

followed in two days. Only twice did an auroral maximum precede a magnetic maximum by one day and only once by two days. Curve (*a*) of Figure 10 shows the number of times auroral maxima fell on or near magnetic maxima.

Both curves show a sharp rise on the date of magnetic maxima, a high value on the following day, and a fall two days afterwards. In each case the rise is much steeper than the fall. This agrees with the suggestion made by E. O. Hulburt[5] that increased auroral activity occurs on the same or the following day after a maximum in the magnetic-character curve.

The magnetic data obtained at Little America have not yet been analyzed. When this has been done, it is hoped that the relationship between magnetic and auroral activity at Little America will be brought out in greater detail.

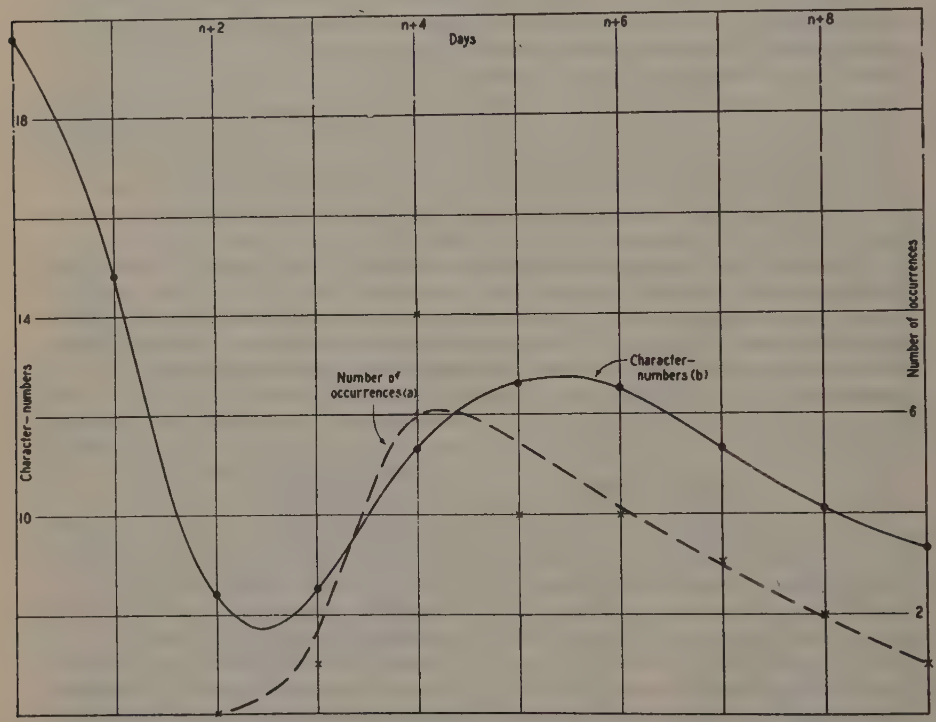


FIG. 11—Short-period change, mean auroral character-numbers (*b*), compared with number of occurrences (*a*), Little America, April to September, 1929

Short-period change in auroral character—In this particular record a period of variation of from four to six days is evidenced. Using the smoothed values of auroral character-numbers, the mean character-numbers for 1, 2, 3, . . . 9 days after each day of maximum auroral character-number are shown in graph (*b*) of Figure 11. Days n are days of maximum value, so the mean number is high. The number

[5] On the ultra-violet theory of aurorae and magnetic storms, Phys. Rev., **34**, 344-351 (1929).

falls to a minimum at two and three days afterwards and then rises to a high value at five to six days after the selected series of days. The number falls off after six days; that is, on the fourth day after a maximum in activity the auroral character-number begins to increase, reaching a high value on the fifth to sixth day and falling afterwards.

Graph (*a*) of Figure 11 shows the number of times when a maximum followed a maximum in from two to nine days. A period of four days is most strongly indicated.

In this record, therefore, a period of from four to six days is evidenced. Dr. Bartels considers this seemingly short period to be an accident for any particular series of observations, depending on the time-interval between groups of sunspots.

Twenty-four-day to 32-day period in auroral character—The mean auroral character-numbers for each day from 24 to 32 days following a day of high auroral number are plotted in graph (*b*) of Figure 12. It is seen that the character-number for 27 days is higher than that for any other day in the interval, and that the rise to this value is more rapid than the subsequent fall.

Curve (*a*) of Figure 12 shows the number of times a period of from 24 to 32 days actually occurred between maxima in the auroral-char-

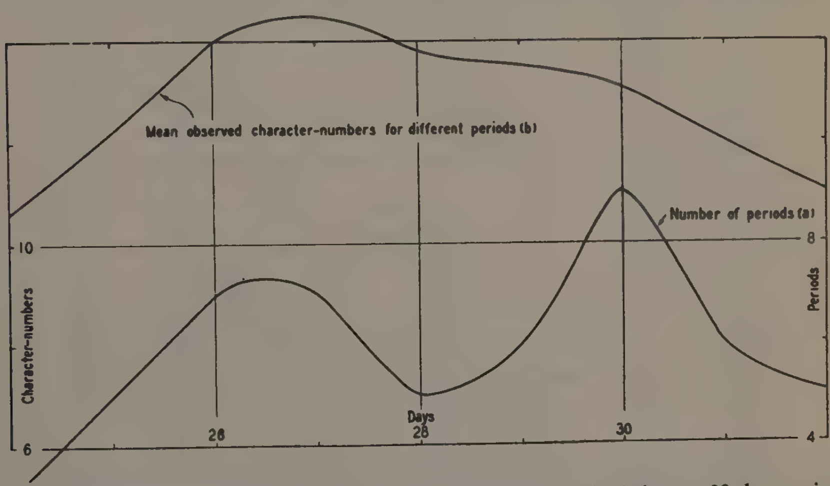


FIG. 12—Mean auroral character-numbers (*b*), and indicated 24-day to 32-day periods (*a*), Little America, April to September, 1929

acter curve. Two high values appear in this, at 26.5 and at 30 days, with a marked decrease at 28 days. However, the mean value of 53 periods of from 24 to 32 days was 28 days. A maximum on the 27th day following a given maximum seems most strongly evidenced, though the period from 26 to 30 days following a high auroral value is of higher auroral character than the remainder of the 24-day to 32-day interval. This period corresponds to the period of rotation of the Sun.

Diurnal change in direction—Hourly smoothed values for each month of the number of times aurora was seen in various directions were computed. In Figure 13 the diurnal change in direction is plotted for each month. Instead of plotting the values for each direction, which

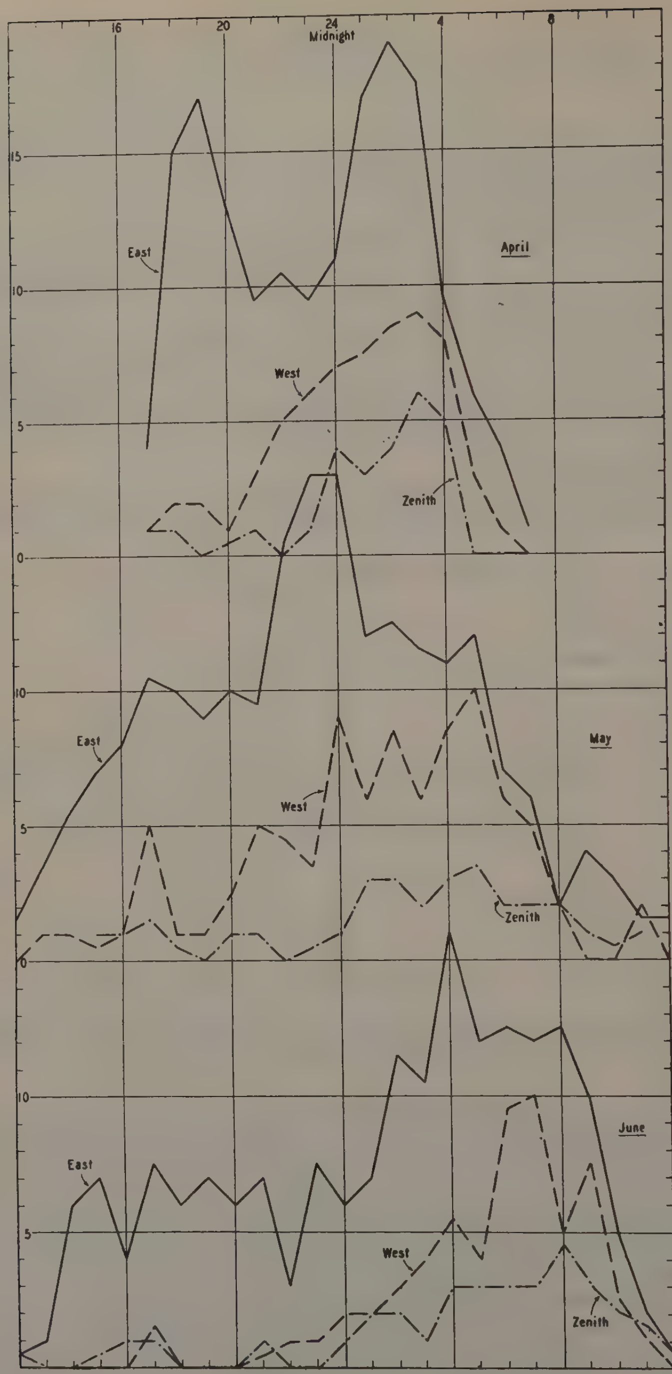


FIG. 13—Monthly mean diurnal change observed sectors auroral displays, Little America, 1929 ("east", "west", and "zenith" indicate N-SE, S-NW, and overhead sectors—165th west meridian time)

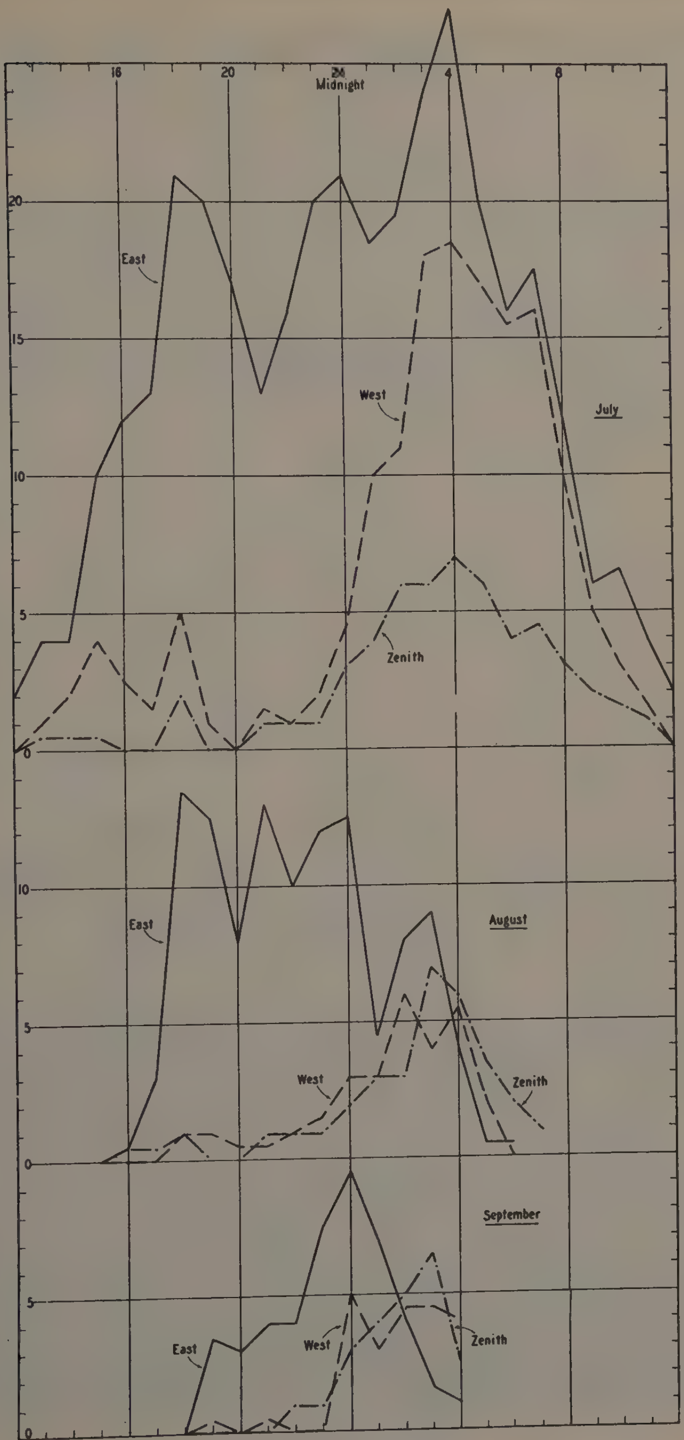


FIG. 13—Continued

method tends to confuse the real change, only three curves were drawn —(a) the number of displays seen in the sector N-SE in which the majority of displays were seen, (b) the number in the minimum sector S-NW, and (c) the number of displays seen overhead at the base-station. (Sectors N-SE, S-NW, and overhead are designated "east", "west", and "zenith", respectively, in Figures 13 and 13*a*.)

The smoothed values of Figure 13*a* show the diurnal change for the whole period, which is also evidenced in each month. Throughout the 24 hours the number of displays in the east sky is greater than that in the west. The displays in the east sky are fairly equally distributed before and after midnight, but the number of displays seen in the west is much greater after midnight than in the evening hours. The number of auroral displays seen at zenith parallels the curve for west sky. This is because the usual progression of display was from the east, rising to zenith and passing to the west later in the night. The time of greatest

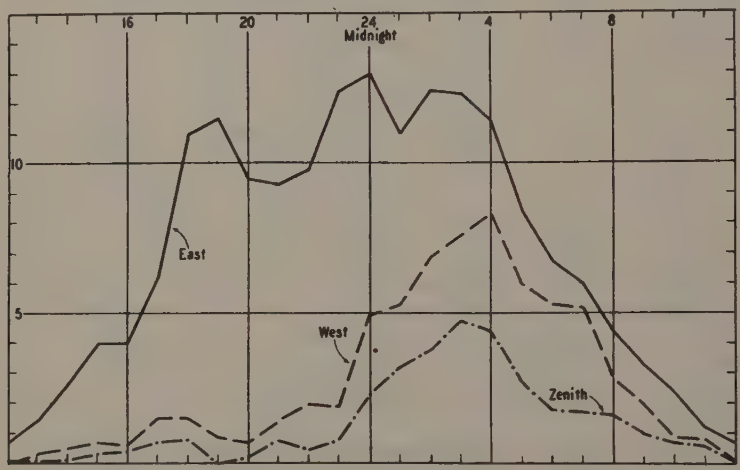


FIG. 13*a*—Mean diurnal change in directions auroral displays for the whole period shown in Figure 13

activity overhead, 3^h, coincides with the times of greatest auroral character-number and greatest frequency. In the directional curves, as in frequency, a rise in number occurs between 17^h and 19^h in all directions, followed by a lull at 20^h. September and, to a lesser extent, August show a greater proportion of displays in the west sky in the morning hours. These months also show a greater proportion of overhead displays.

Number of displays in each direction—Compilation of the number of displays in each direction for each month shows that the values for directions north-northwest (NNW), north-northeast (NNE), etc., are less than for north (N), northeast (NE), etc. This is because of the tendency for an observer to write a more general direction in recording a display. The values have been smoothed according to the following method: Number in north = (NNW+2N+NNE)/4, etc., for the means for the whole period using numbers seen in directions indicated by observations NNW, N, NNE, etc. Figure 14 shows monthly diagrams

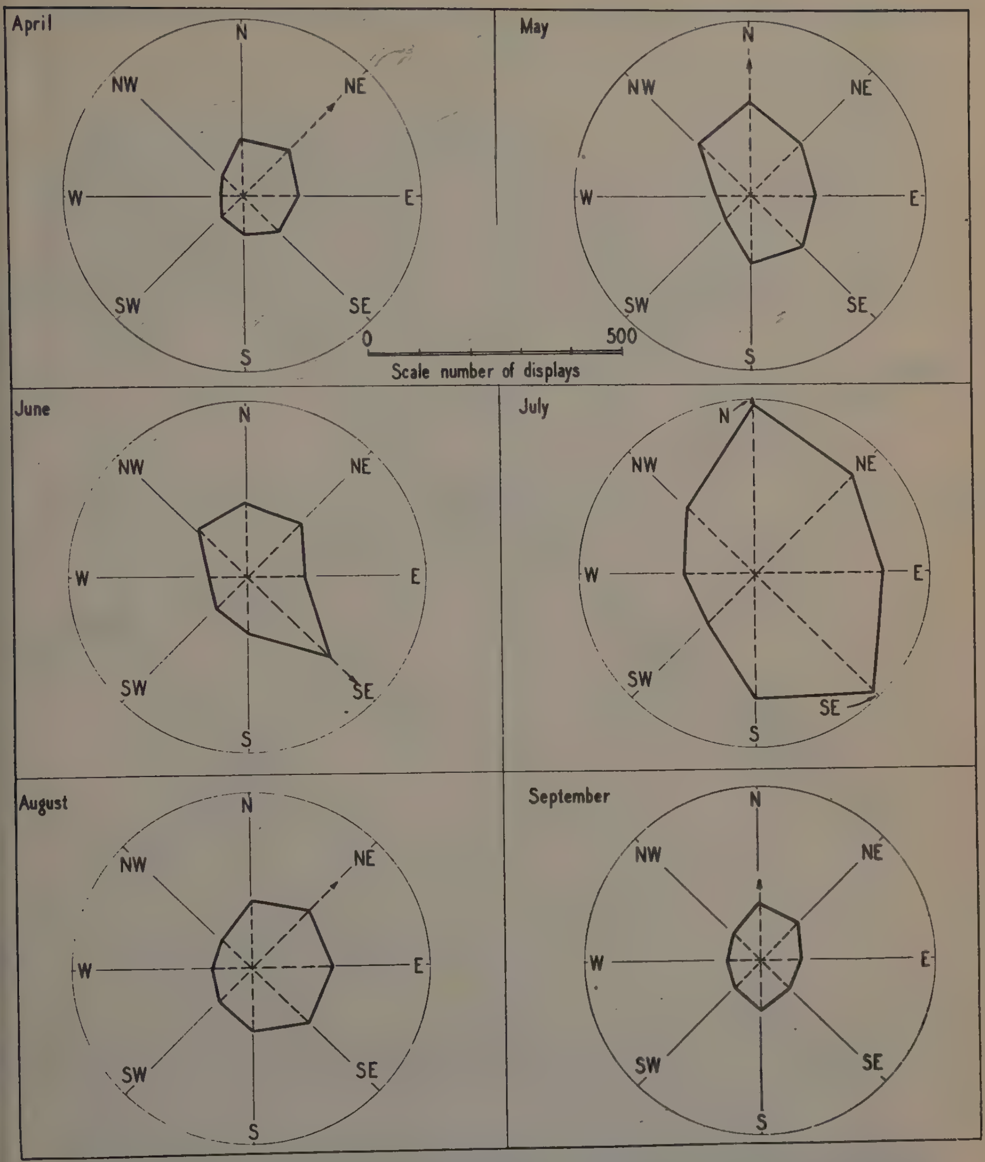


FIG. 14—Total numbers of auroral displays seen in cardinal and intercardinal directions, Little America, 1929

of the actual number of displays seen in each direction N, NE, etc. The figures for the intermediate directions NNE, etc., are not marked. Graph of Figure 14*a* gives the smoothed values for the whole period.

There are more displays in the east sky than the west, though this difference is less in September. The greatest number of displays was seen in either northeast or north for all months except June, during

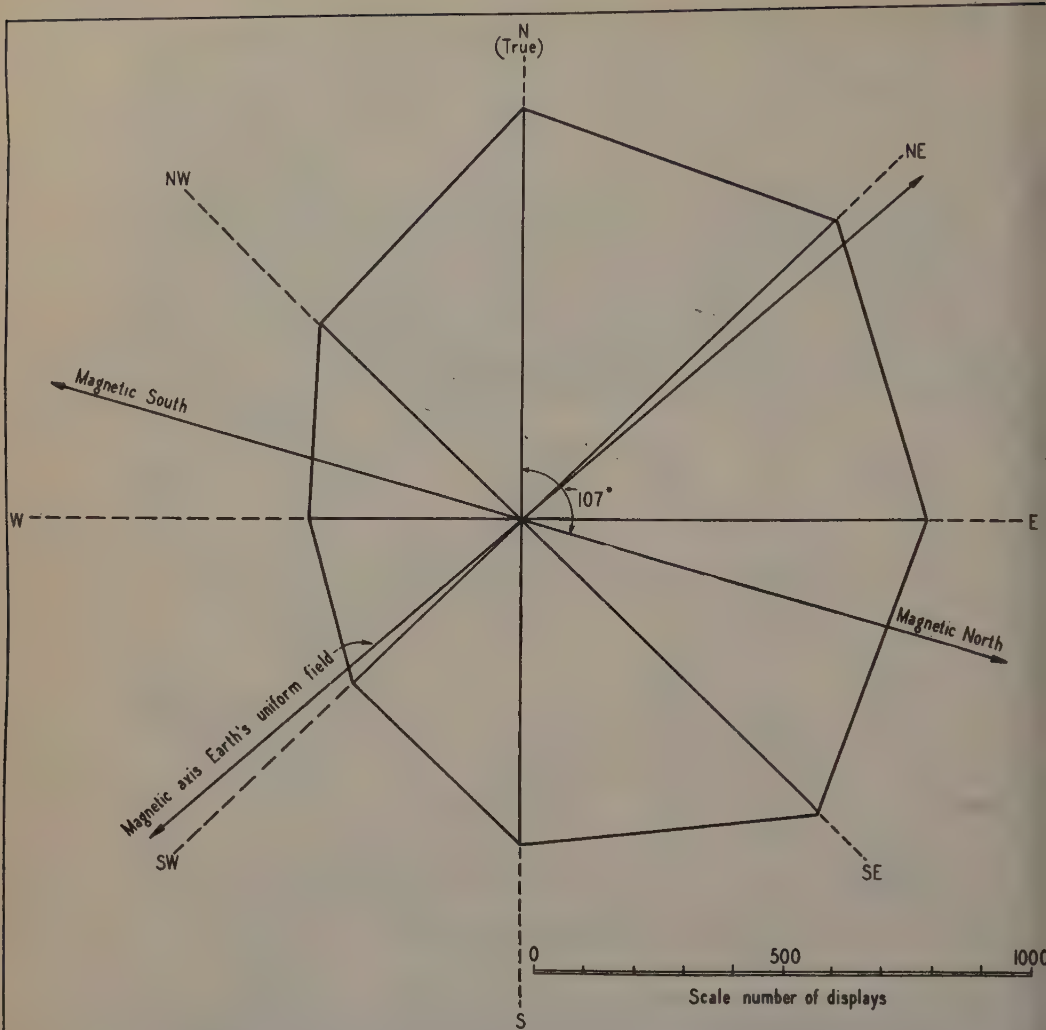
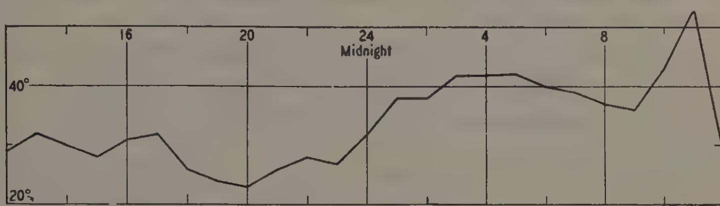


FIG. 14*a*—Total numbers of auroral displays seen in cardinal and intercardinal directions, Little America, April to September, 1929

which the greatest number were in the southeast. On Figure 14*a* the direction of the compass is marked (declination 107° east). The direction to the south pole of the Earth's magnetic axis is, however, nearer to southwest. The distribution of displays seems more symmetrical with respect to the latter direction, a minimum between west and southwest and a maximum between northeast and east.

Diurnal change in altitude of aurora—Altitudes recorded in the log are eye-estimates. For this reason and also because the taking into account of each angle recorded would be too laborious a process, the following method of obtaining mean altitudes was adopted: All observa-

tions recorded between the horizon and 30° were classed 1, those between 30° and 60° were classed 2, those between 60° and 90° were classed 3, and those overhead were classed *Z*. The number of observations for a given half-hour during each month in each class was found and the mean altitude for each class assigned to it. The mean altitude for a half-hour was then found by adding up the total angles for each class and dividing by the number of observations. Displays recorded as 30° and 60° were classed *1,2* and *2,3*, respectively, while *Z* was given the value 90°. Thus for records of 8 observations class 1, 3 class 2, 2 class 3, and 1 class *Z* the mean altitude adopted is $(8\times15°+3\times45°+2\times75°+1\times90°)/14=39°$. The large number of observations available at altitudes that could only be regarded as approximate, justifies this method of estimating means. The assumption of 15° as a mean



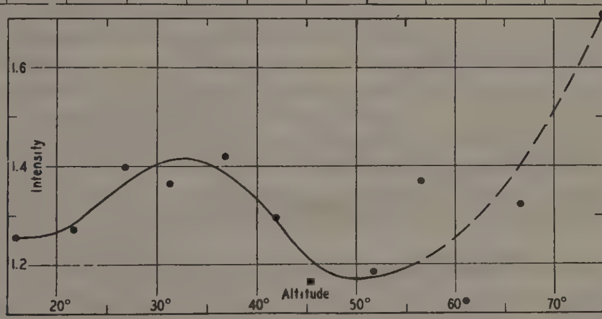


FIG. 15—Smoothed mean hourly altitudes auroral displays seen, Little America, April to September, 1929 (165th west meridian time)

FIG. 17—Relation mean auroral intensities and altitudes, Little America, April to September, 1929 (smoothed values)

altitude for all observations between 0° and 30° is thought entirely reasonable within limits of error to be expected in estimations by eye of a phenomenon subject generally to rapid movement. The diurnal change resulting from mean calculated altitudes and smoothed hourly means is illustrated in Figure 15. The part of the graph during 9^h to 15^h is not as certain as the balance because of the fewer data—indeed there is considerable doubt about the high value for 11^h. A mean altitude of about 30° at 16^h to 17^h falls to 23° at 20^h and then rises steadily to 40° and over between 3^h and 6^h, falling to 36° at 9^h. There seems to be a sharp rise in altitude of displays seen in late morning, with a maximum at 11^h, falling rapidly to noon; but this is no more than a suggestion, owing to the much fewer observations at these hours.

Altitude through whole period—The percentage-proportion for each month of the number of displays in each of the three altitude-zones for different sectors of the sky was compiled. Figure 16 shows the propor-

tion in each zone for each month—(*a*) for the maximum sector N-SE, (*b*) for all directions, and (*c*) for the minimum sector SSW-WNW. In each of these the slopes of the curves are the same; that is, the percentage-proportion in the lowest altitude-zone in general decreases from April to September; percentage in middle altitude-zone is nearly constant from April to August, when it rises; percentage in highest altitude-zone rises from April to September. An increase in mean altitude in September is evidenced, and the lowest value occurs in April. The change during the interval, though slight, shows an increase in mean altitude from April to September.

Altitude and intensity of display—Mean altitudes and mean intensities of display for each day, and the mean intensities corresponding to

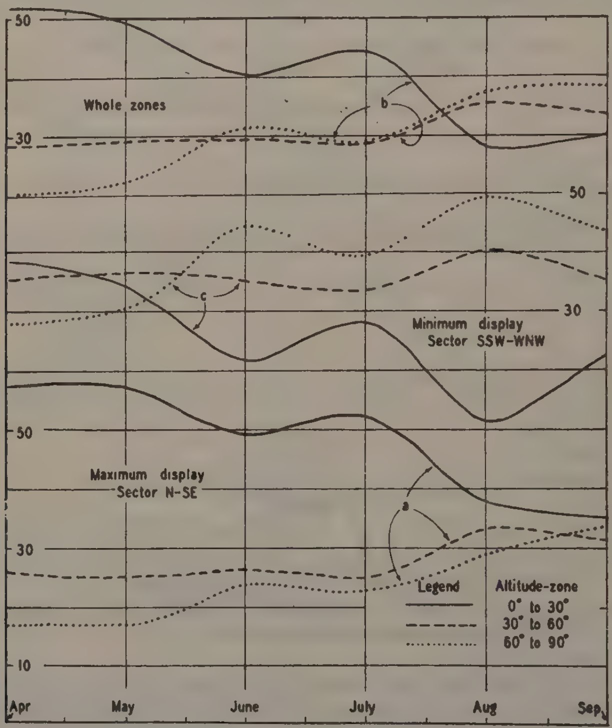


Fig. 16—Total auroral displays in altitude-zones for each month expressed as percentages of the totals recorded, Little America, 1929

given altitudes, were grouped for each 5° of altitude and the corresponding mean intensities found. The relation between altitude and intensity is illustrated in Figure 17. A marked increase in apparent intensity is indicated from 15° to about 34° and then a falling off to a minimum at 50°. Intensities at higher altitudes than 50° are more widely scattered, but in general increase from 50° to 65° and rise sharply at altitudes greater than 65°. This curve must be regarded only as an approximation to the relation between altitude and intensity, since not only are the intensities eye-estimates, but these estimates are bound to be low

for displays at low altitudes and therefore at greater distances from the base. Although we have taken altitudes without regard to direction, the great majority of displays seen at low and moderate altitudes were in the east sky. The maximum in the curve at altitude 34° suggests that the brightest part of an outer auroral belt exists at a distance corresponding to this altitude. If we assume 100 kilometers as a mean height for auroral displays (Störmer), this bright portion is about 140 to 150 kilometers from the base-station in the sector north to southeast. The curve indicates a decreasing mean intensity further away, but this cannot be accepted as more than a possibility because of the underestimation of intensity of distant aurora. It appears, however, that the decrease in intensity from altitude 34° to a minimum at 50° really indicates that a zone in which aurora is considerably less bright lies between an outer auroral belt and the base-station. If this were not the case one would expect that mean intensities taken from a large number of observations would continuously increase, owing to the increasing proximity to the observing-station. This zone of low intensity, on the assumption of an auroral altitude of 100 kilometers, lies between 110 and 70 kilometers from the base. There appears to be a real increase in intensity nearer Little America, though this may be only apparent, due to the shorter distances involved.

Little America is distant some 15°.6 from the south pole of the Earth's magnetic axis. This pole of the axis is very nearly southwest from Little America. This places the zone of low auroral intensity some 17° from the south pole of the magnetic axis. Further away than 17° stretches a belt in which auroral intensity is probably greater than in the belt nearer the axis. These belts extend beyond the horizon from Little America in either direction though, whereas aurora was very often seen on the horizon away from the axis, this was more rarely the case towards the axis.

Direction of arches—Auroral arches were most often seen in the following positions: NE-SE, N-SE, NW-SE. Thus they ran generally from north to south. They were fairly often recorded from north through zenith to south. In section III(*a*) typical changes are noted as, for instance, the appearance of an arch in the east sky at the beginning of a display. The formation of spiral and "horseshoe"-curtains was observed on several occasions. These were associated with particularly active displays. In such cases the movement of a curtain was usually such that the north end moved westward and the south end eastward, the latter motion being most pronounced. There does not seem to be a marked relationship between trend of arches and curtains and position of the Sun.

Possible lull in auroral activity in May—L. C. Bernacchi, in charge of auroral observations on the *Borchgrevink* (1899) and Scott (1902–03) expeditions, remarked on the tendency indicated in observations of 1902–03 for altitude to increase from month to month and also suggested that there was a decrease in auroral activity in May after a sharp rise in April, subsequently followed by high values in June and July. To test this, a tabulation was prepared giving number of days on which aurora was seen in each month by different antarctic expeditions, and the percentage of the total number of days for the year on which aurora was seen was compiled for each month. This method was used because information as to the number of days on which aurora was seen is avail-

able for several expeditions. The data for 1911–12 from the Scott Expedition are not given a form that distinguishes month from month, and therefore were not included.

Figure 18 shows the proportion of auroral days in each month for records made during nine winters and also the mean for the whole series. Eight out of the nine curves shows a drop from April to May. The single exception is the curve for data of 1899 at Cape Adare. The mean curve shows a sharp rise from March to April, a drop in May, and then the maximum value for the winter in June and July, falling steadily through the spring months. How far this tendency would be altered by investi-

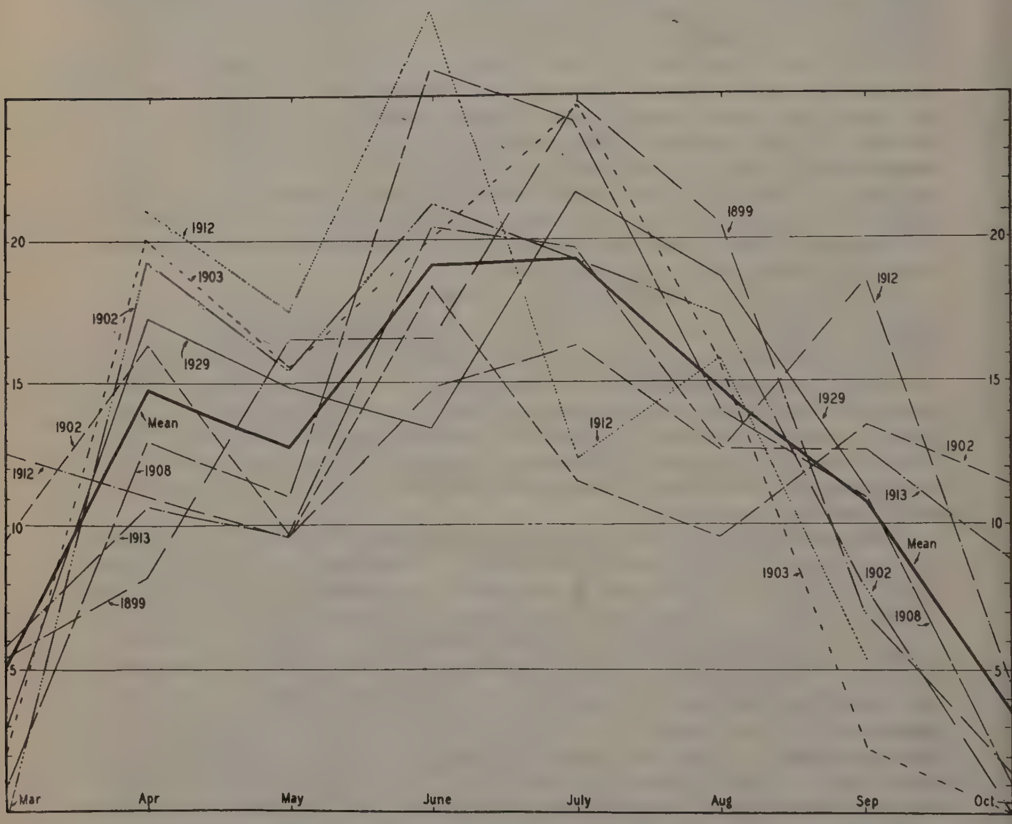


FIG. 18—Monthly percentages of total auroral displays recorded, March to October, various antarctic expeditions, during 1899-1929

gating each auroral record in greater detail and taking into account cloud- and light-conditions, it is hard to say. When the data for Little America are plotted as a monthly percentage of total days on which aurora was seen, the curve follows the others in that it falls from April to May and in June also, and then rises. But after taking into account the conditions for each observation, it was seen that auroral frequency actually decreased all along from April to September. Since the various records are not compiled on a uniform plan, comparison is difficult.

Low-altitude aurora and sound—The importance of taking note of low-altitude aurora or any sound accompanying aurora was stressed, but no evidence was obtained of either occurrence. It was at first thought that certain crackling, swishing noises were associated with aurora, but it was found that these noises occurred only when the temperature was below −50° F, and were due to the freezing of the moisture from the breath. One might think such a cause would be very quickly discovered, but, in the writer's own experience, the noise was not at first associated with the breath. It seemed to come from a short distance to the side and was not regular.

At the base-station there was a view to the horizon in all directions. This precluded the chance of seeing an aurora against a mountainous background. However, aurora was frequently seen through high cirrus cloud, but on no occasion was any remark made suggesting that the auroral display was lower than the clouds.

Summary

Aurora was seen at the winter-station on four days in March, 23 in April, 20 in May, 18 in June, 29 in July, 25 in August, and 15 in September—a total of 134 days in the seven months March to September 1929. Aurora was seen on three days of March 1930 while en route from Little America to New Zealand.

From April 3 to September 26 aurora was seen on over 90 per cent of all clear or only partly clouded nights. A better estimate of occurrence is the proportion of observations when aurora was seen to the number when cloud- and light-conditions were such as would allow its being seen. This proportion was 48 per cent. The comparable figures were: Scott Expedition of 1911 at Cape Evans, 36 per cent; Scott Expedition of 1911 at Cape Adare, 64 per cent; and Mawson Expedition of 1912-13 at Cape Denison, 52 per cent. Even though 1929 was a year near the maximum of the sunspot-cycle, the proportion for Little America is considerably below the Cape Adare proportion for a year near sunspot-minimum.

A marked feature of aurora at Little America was the progressive change through the period of observation of the following phenomena: (*a*) The average intensity of aurora was greatest in April, least in September, and decreased during the months between; (*b*) the ratio of the number of displays seen to the number that could possibly have been seen was greatest in April and decreased through the period to September; (*c*) although the majority of displays was seen in the eastern sky, the proportion seen in the west increased during the period April to September; (*d*) the proportion of displays at a high altitude was least in April and greatest in September, while the mean altitude of a display increased between April and September; and (*e*) the proportion of displays exhibiting ray-structure, though less than half the total from April to August, increased in September to more than a half.

The brightest displays occurred on the following days, which correspond to Greenwich noon of the day mentioned until noon of the next: April 16, 17, 18, 29; May 4, 13, 15; June, none; July 7, 9, 10, 11, 15; August 12, 13; and September 14. (It is to be remarked that June was cloudy during latter half of month, when a few bright displays probably were obscured. This reduced the mean intensity for the

Fig. 19—Sketch-map antarctic region showing route *City of New York* from Dunedin, New Zealand, to Little America and return

month and possibly explains the departure in June data from the progressive changes from month to month noted in this discussion.)

Periods of greatest auroral activity were: April 11, 16-19, 29-30; May 3-7, 12-18; June 3, 6-9, 12-13, 16, 29 to July 2; July 4-13, 14-16, 26-29; August 3-4, 13-15, 23-27, 31 to September 2; and September 8-14.

A double auroral belt is indicated by the relation observed between altitude and intensity of display—an outer belt of greater intensity, separated by a narrow zone of much diminished intensity, situated about 17° from the south pole of the Earth's magnetic axis.

Comparison of auroral character-numbers for days with the international magnetic character-numbers, shows marked evidence for the occurrence of an auroral maximum on the same day or one day after a maximum in the magnetic character-curve.

A period of from 26 to 30 days is evidenced corresponding to the period of rotation of the Sun. A short period of from four to six days also appears, due, possibly, to the accidental spacing of sunspot-groups at these intervals.

In general, the bright displays were in late afternoon, most frequent and brightest about 18^h local time, when the average intensity during 24 hours was greatest. These displays were usually low in the east sky, being comparatively quiet and without ray-structure. The appearance of their being relatively quiet may be due to their distance from the observing-station. A lull characterized conditions in the late evening. After 22^h activity and altitude of aurora increased and ray-structure became more pronounced, until a maximum in all three features was reached at about 2^h to 3^h. The number of displays without ray-structure was greater at all hours—a preponderance very marked in afternoon and evening, but much less on the morning side of the peak of activity reached at 2^h to 3^h.

The fact that ray-structure increased rapidly as the display neared the base suggests the possibility that the low quiet displays seen earlier in the evening may have had ray-structure, but, owing to their distance and because of the much smaller area of illumination of thin pencils compared with wide bands, the rays were not seen.

The development of auroral displays at the winter-station may be likened to the advance of a tide from the eastern horizon, advancing and retreating like waves on a beach, but rising slowly through the afternoon and evening The afternoon and early evening displays correspond to activity in the outer brighter auroral belt, the late evening lull to the low-intensity zone, and the subsequent increase in activity and altitude to the inner zone. The high auroral activity of the afternoon and early evening seemed to occur in the outer belt, with little activity in the inner belt. After the lull at 22^h, activity increased rapidly in the inner belt, but occurred in the outer belt also.

There is a parallel between the diurnal and the seasonal change. In April the mean intensity was greatest and altitude least. In September altitude was greatest, intensity least, and ray-structure more pronounced. It appears that in April, as in the afternoon hours, activity was more confined to the outer auroral belt and that later in the winter activity was greater in the inner belt than in April, but occurred in the outer belt also.

Comparison of times of occurrence of aurora in the antarctic and in northern countries for 1929 is postponed until the magnetic records obtained at Little America are completely analyzed, and are available for comparison also with the magnetic records of northern stations.

In conclusion, the writer wishes to express his thanks to Rear-Admiral Richard E. Byrd and the members of the Expedition for their cooperation in the auroral work, and especially to the six observers who undertook so much extra duty for this purpose. C. C. Ennis and S. L. Seaton, of the staff of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, prepared the graphs showing results. The

Expedition is further greatly obligated to the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and to its Acting Director, J. A. Fleming, who, besides providing the author the opportunity and facilities to complete the discussion as a member of the staff of the Department, has so generously given experienced advice and stimulus in the discussion and presentation of the results.

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AIR-POTENTIAL REGISTRATION AT THE MANILA OBSERVATORY, OCTOBER 1927 TO DECEMBER 1930

BY C. E. DEPPERMANN, S.J.

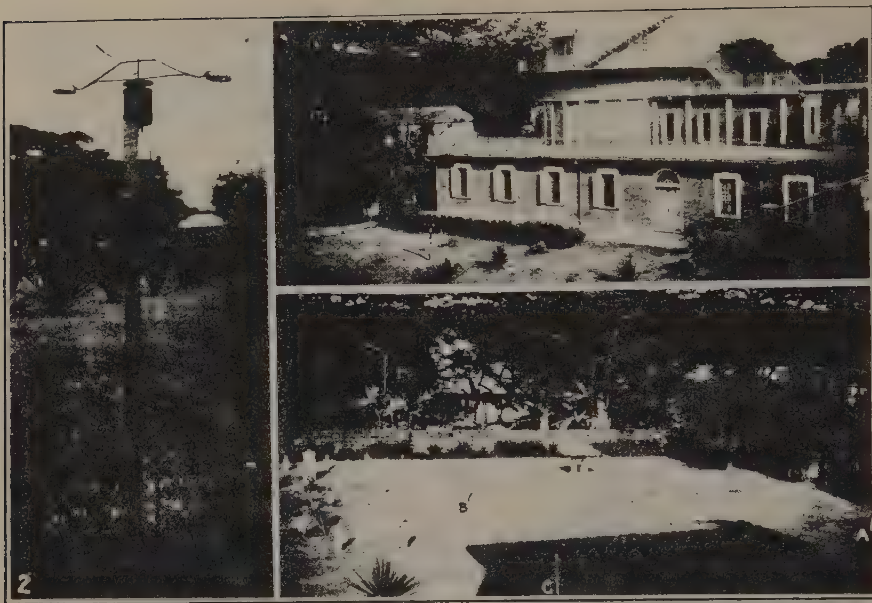
Features of site and equipment—Registration of air-potential at the Manila Observatory began October 1927, a Wulf bifilar electrometer adapted for registration being used until April 1928. Thereafter a remodeled Mascart quadrant-electrometer was used. The results up to the end of 1928 were reported in a preliminary paper[1] by the author in which details of site, installation, and discussion of data are given.

The Manila Observatory is in latitude 14° 35′ north and longitude

FIG. 1

121° 02′ east. The general features of the surrounding region are shown in Figure 1. The two ionium-collectors are supported by a post-type insulator (see *A*, Figs. 2 and 3), all of which were supplied by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The collectors stand 1.9 meters above the ground at a point on the lawn 10.4 meters (see Fig. 5) from the nearest building, in which the electrometer is now housed. This building is a one-story structure, with a roof railing the top of which is 7.5 meters from the ground-level. Observations for standardizing the recording-station are made with the Simpson stretched-wire method at a point near the center of the same lawn (see Figs. 4 and 5), in which the post-insulator is located, the

[1] Initial studies in atmospheric electricity at the Manila Observatory, October 1927–December 1928, Manila, Weather Bureau, 1929.



FIGS. 2, 3, AND 4

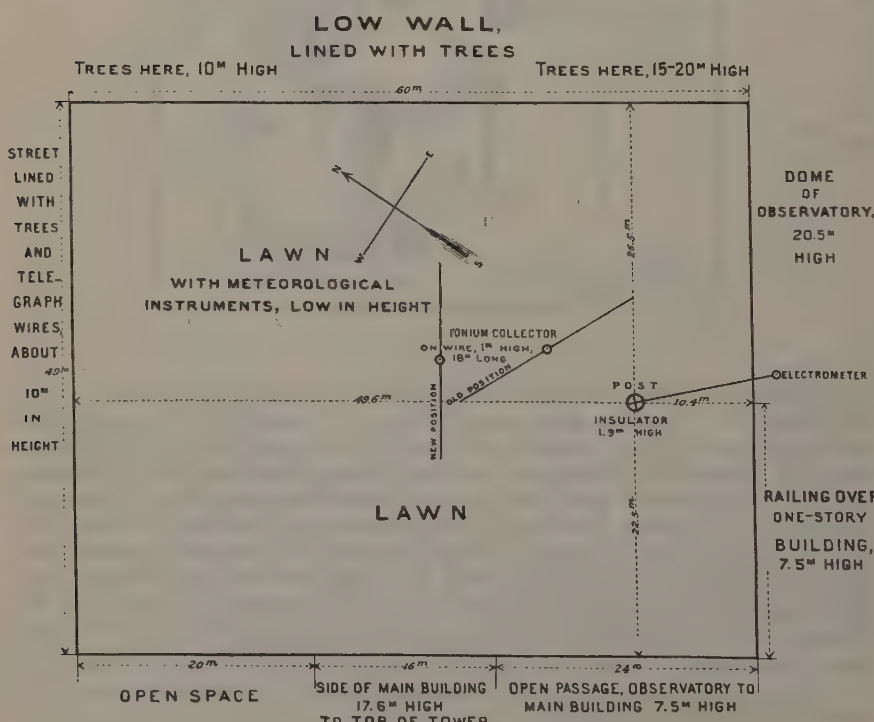


FIG. 5

value of 1.1 being thus obtained for both the "old" and "new" positions of the stretched-wire station. This site is, however, not an ideal one for such standardization-observations, since the lawn (60 by 49 meters), as may be seen from Figure 5, is surrounded on two sides by either telephone wires or trees ranging in heights from 10 to 20 meters; on another side by the dome of the astronomical observatory (height, 25 meters), and a building (height, 7.5 meters), and near the center of the remaining side by a tower (height, 17.6 meters), and a low building (height, 7.5 meters). In view of this situation, it is obvious that the potential at the standardizing-station is distorted and consequently the factor to reduce recorded volts to volts per meter has been estimated as really about 1.3—an estimation based upon data given by Kähler[2] and Mathias.[3] Because of the uncertainty in this reduction-factor, it is considered only tentative and the values hereafter given are expressed in volts as recorded.

The difficulty in maintaining adequate insulation in the tropical climate of Manila is considerable. As is so often the case, spiders are the source of most insulation difficulties, although small lizards, frogs, and moths occasionally foul the insulation. Some protection is provided by the use of tree tanglefoot, but in this climate it must be renewed very frequently. To provide better protection against the driving tropical rains, anemometer-cups were placed just above each collector to serve as a shield. Dew is here also a source of some interference and is a possible cause of the low reading near dawn, especially during winter, when even the underside of the collector becomes covered with dew. This deposit is sometimes thick enough to seriously reduce the activity of the collectors, as is evidenced by the fact that the recorded potential is on occasions found to be higher immediately after wiping off the dew. Despite these various difficulties, it is thought that serious effects from this source have been obviated. After some experience one can readily tell when a record has been spoiled by poor insulation, and in the reduction all such records have been discarded.

Results—The results are the means of instantaneous values scaled on the hour. The hourly means from all satisfactory registrations for the individual years and for the three-year period expressed in volts are given in Table 1 and are shown graphically in Figure 6. As will be seen, the principal maximum occurs between 7 and 9 o'clock in the morning and the principal minimum appears about four to six hours earlier. A very similar type of diurnal variation is shown in the values obtained from selected days, the means of which are also given in Table 1 and shown graphically in Figure 6 (for which means A were used). Selected days or so-called "normal days" are chosen on the basis of meteorological conditions rather than by the character of the electrical record. The term "normal" as used in the later years at this Observatory refers to days on which there are practically cloudless skies both day and night. The electrical basis of classification which is sometimes used does not seem feasible at this station, since days in which no negative potential occurs are exceedingly rare. This in itself is a striking observation which is receiving further investigation.

Another disturbing feature at this station is the abundant rain which occurs during July, August, and September and, at times, in June.

[2] Luftelektrizität, Berlin and Leipzig, 1921, p. 3.
[3] Traité d'électricité atmosphérique et tellurique, Paris, 1924, p. 13.

TABLE 1—*Air-potentials in volts, Manila Observatory, Philippine Islands, mean values for all-day and for normal*[a]*-day groups, October 1927 to December 1930*

(The values are means of instantaneous values on the hour, 120th east meridian time; approximate reduction-factor to be applied to reduce to volts per meter, 1.3.)

Mean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Year
October 1927 to November 1928																									
All	47.4	40.9	42.8	40.5	40.4	55.1	73.1	104.6	100.9	90.6	79.5	75.7	64.2	64.6	59.4	63.7	63.1	61.0	63.8	53.0	51.0	64.9	55.0	50.5	62.5
Normal																									
A	57.3	49.9	48.6	49.8	48.2	61.4	88.9	121.3	118.7	95.0	77.3	72.5	64.6	70.9	75.1	57.1	67.4	68.5	69.4	64.9	55.4	61.1	58.4	58.8	.....
B (24)	51.9	47.1	44.2	43.6	44.3	50.5	74.0	132.4	119.5	85.0	75.4	72.7	64.3	76.2	76.8	66.0	70.5	74.4	75.2	72.0	58.0	60.5	53.1	57.3	68.5
January to December 1929																									
All	54.6	52.8	47.2	45.0	40.6	63.1	83.1	99.8	85.4	76.4	65.2	60.0	52.3	45.6	47.4	45.8	53.4	48.4	50.8	46.4	51.7	59.5	58.6	54.0	57.8
Normal																									
A	56.5	49.7	53.0	47.7	42.5	67.0	95.3	121.1	97.0	83.7	67.1	51.6	44.1	36.0	34.4	30.4	37.1	32.8	36.9	40.4	42.7	48.8	52.1	58.4	.....
B (25)	41.8	37.9	36.8	37.9	33.6	60.9	79.9	106.7	93.5	78.9	61.3	48.8	37.6	35.4	28.5	20.2	36.0	27.1	30.8	33.6	35.9	42.9	43.2	46.0	47.3
January to December 1930, excluding July																									
All	51.6	53.6	50.9	46.6	40.8	47.1	68.9	101.2	106.9	88.2	73.3	61.2	59.1	51.6	50.5	54.9	59.4	60.1	66.0	63.1	57.0	63.5	64.6	55.0	62.3
Normal																									
A	54.0	58.5	53.1	47.6	55.7	62.6	72.4	146.2	136.8	113.5	85.6	68.6	64.4	51.1	48.9	55.5	58.4	65.5	65.1	63.1	60.6	59.9	71.6	62.0	70.0
B (*)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....

NOTES: [a] The term "normal" refers to meteorological conditions defined as practically cloudless sky, day and night. *A* includes complete and fragments of "normal," while *B* includes complete 24-hour values for number of days indicated in parentheses ( ) following *B*. The recorded values for July 1930 were not used because of suspected defective insulation. * Individual hourly daily values for "normal' days not yet supplied for selection.

TABLE 2—*Air-potentials in volts, Manila Observatory, Philippine Islands, normal*[a] *days, February 1931*

(Instantaneous values on the hour, 120th east meridian time; approximate reduction-factor to be applied to reduce to volts per meter, 1.3)

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Mean
1	....	....	....	....	....	....	....	....	....	....	65	70	35	32	35	−27	10	15	60	74	45	73	43	32	
2	65	50	50	40	30	51	60	185	210	155	180	72	70	45	44	−10	−35	10	20	30	24	40	35	32	
3	54	17	20	25	−5	7	15	160	130	90	−20	55	75	90	25	17	15	25	68	42	35	37	30	25	
4	17	7	8	5	−5	−4	−10	130	106	60	[50	90	85	92	80	16	12	20	63	40	32	26	13	7]	
5	....	....	....	....	....	....	....	....	[85	75	60	32	15	20	47	50	30	25	38	32	28	30	20]	....	
10	....	....	....	....	....	....	....	....	....	....	[27	25	−32	−30	−30	−40	−5	28	60	75	50	45	40	35]	
11	45	45	70	90	96	35	95	130	85	10	[11]	....	....	....	....	....	....	....	....	....	....	....	....	....	
13	[60	4	−7	−6	−30	−10	−30	40	75	137]	120	70	50	−15	−17	30	35	60	85	130	95	115	100	77	
14	23	107	70	60	75	64	67	110	118	147	48	30	55	−5	−35	−15	−14	23	80	105	50	110	68	35	
15	45	50	70	22	10	−30	15	55	140	130	70	25	−50	−35	−55	−8	−12	27	75	65	115	105	100	50	
16	50	55	24	42	50	45	50	82	26	−60	15	5	51	10	23	−60	−24	67	100	200	115	90	65	80	
17	100	119	40	33	85	37	85	150	85	115	137	140	60	40	−40	7	16	40	85	95	85	74	58	54	
18	33	32	5	30	37	60	47	190	174	160	122	[105	90	110	15	−60	−25	36	60	65	120	50	35	40]	
19	....	....	....	....	....	....	....	....	....	....	....	92	93	(36)	−20	−19	7	28	74	95	76	55	36	38	
20	55	74	55	57	55	−13	100	200	225	205	112	119	80	115	98	20	25	40	72	80	100	27	82	75	
21	94	110	95	90	55	85	135	210	215	182	135	85	110	112	132	185	−18	35	60	73	45	64	63	60	
22	85	93	77	53	60	25	60	120	125	118	80	110	120	110	90	135	23	32	60	90	60	55	64	45	
23	44	70	40	50	15	17	65	66	110	85	112	....	....	....	....	....	....	....	....	....	....	....	....	....	
26	....	....	....	....	....	....	....	....	....	....	....	67	55	84	25	25	24	−10	25	24	17	−5	−3	5	
27	12	10	10	7	6	8	54	190	(134)	78	100	....	....	....	....	....	....	....	....	....	....	....	....	....	
28	....	....	....	....	....	....	....	....	....	....	....	70	60	55	110	80	26	19	50	65	75	73	120	158	
Mean *A*	52.1	56.2	41.8	39.9	35.6	25.1	53.9	134.3	127.7	105.4	79.1	70.1	56.8	48.1	29.3	18.1	5.6	28.9	63.1	76.7	64.8	59.1	53.8	49.9	....
Mean *B*	51.6	59.9	45.3	43.1	40.3	27.6	59.9	141.3	134.5	105.4	91.1	72.1	61.7	48.1	29.6	25.7	5.6	29.4	65.8	83.4	66.9	65.2	61.5	54.7	61.2

NOTE: [a] The term "normal" refers to meteorological conditions defined as practically cloudless sky, day and night. Row "mean *A*" includes all the tabular values; "mean *B*" excludes those values enclosed in brackets [ ]; values enclosed in parentheses ( ) are interpolated.

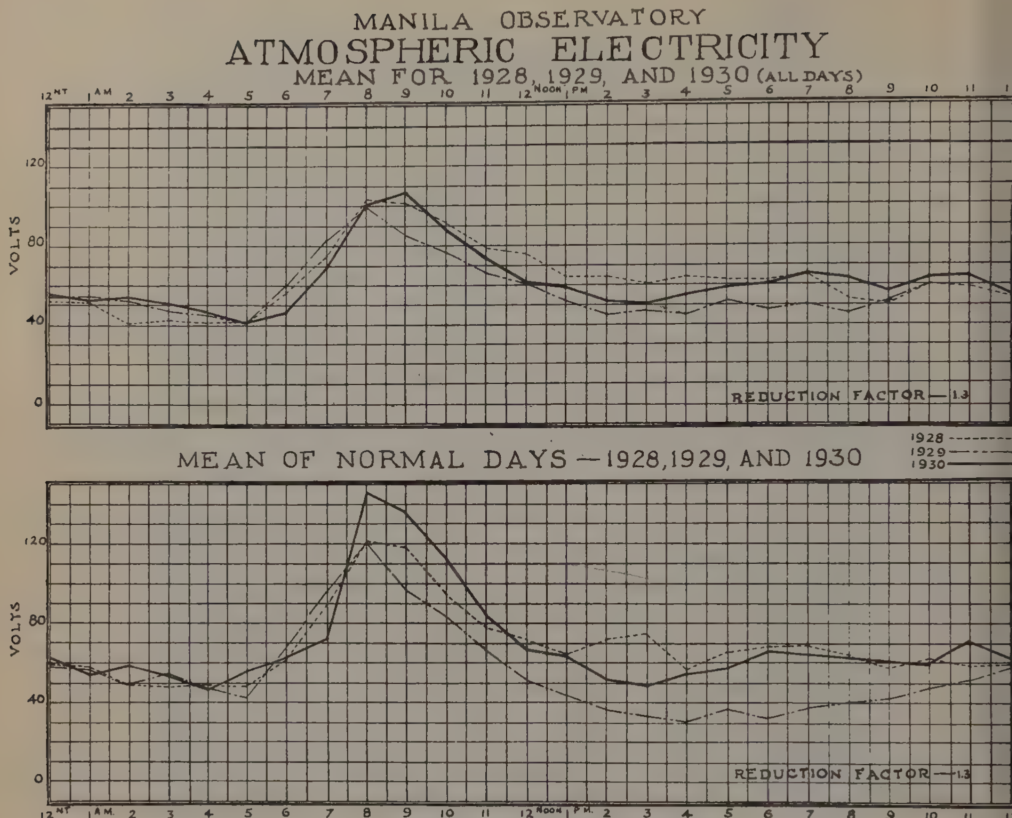


FIG. 6

Typhoons bring much rain and disturbed weather for a week or two at a time, and thus curtail the available data for general studies, since at such times the regularity of the record is completely destroyed.

Winds also play an important part here in determining the character of the changes in air-potential. During some nights, particularly if a northwest wind is blowing, high values often exceeding the usual morning maximum are recorded. However, if the night is calm or the wind from the southeast, abnormally low values are usually recorded. The southeast wind is particularly interesting in this connection, for when it starts to blow, the potential almost invariably drops abruptly and frequently becomes negative, even when the sky is cloudless. This feature is well illustrated by the data for February 1931 (see Table 2), during which a surprisingly large number of normal days occurred in succession. It should be emphasized that although these were days with practically cloudless skies both day and night, negative potentials were recorded on many occasions. The intimate connection between low or negative potentials and southeast wind is well illustrated by the records for February 18-19 and February 27-28, 1931 (see Fig. 7). In August 1928 there occurred at Manila a period of clear weather, with steady

southeast wind of moderate intensity throughout the day and night. During this time the morning maximum was almost entirely suppressed. Although hints at possible explanations of some of the effects here mentioned were made in the preliminary paper referred to,[1] yet the major features remain unexplained, and their investigation is being continued.

A more complete program of observations, including measurements of conductivity, of ionic density, and of condensation-nuclei, will be initiated during 1931. It is hoped this will provide information to disclose the primary factors that affect the interesting changes in air-potential shown by the data submitted here. That these features are largely of local origin was indicated by the series of air-potential registrations made at Sogod (Cebu, Philippine Islands), the latter part of April and early part of May, 1929,[4] which showed none of the outstanding variations which are characteristic of the registrations obtained at Manila.

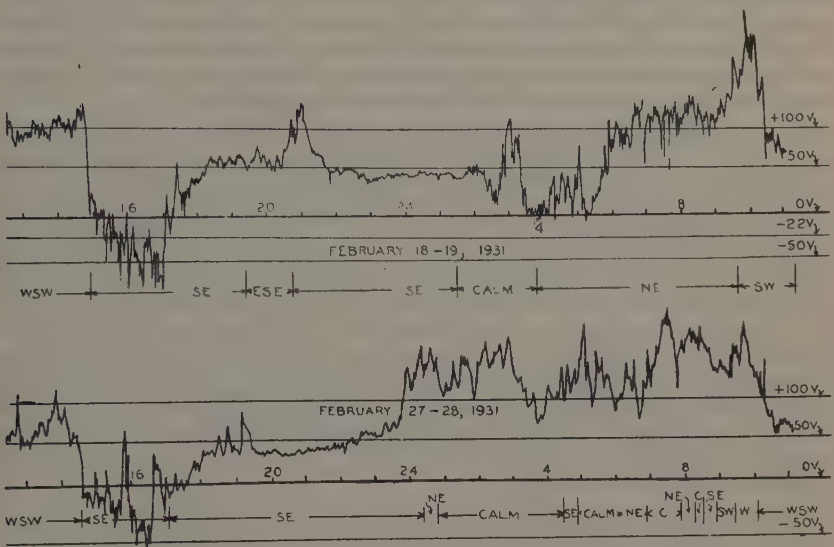


FIG. 7

The matter reported here is thought to be of interest primarily for the problems it suggests rather than for its value in the study of world-wide aspects in atmospheric electricity; in fact, the author counsels against its use for general studies until the series at this station is much more extensive.

PHILIPPINE WEATHER BUREAU,
Manila, Philippine Islands

[4] Terr. Mag., 34, 257-258 (1930).

NOTES

(See also pages 170 and 242)

25. *Magnetic Work at the Dominion Observatory, Ottawa, 1929-30*—Observations of the magnetic elements, declination, and horizontal intensity were made at ten stations along the water-route between Sioux Lookout and James Bay by way of Lac Seul, Root, and Albany rivers. Of these, three are exact and three approximate re-occupations of stations established by the Carnegie Institution of Washington in 1913, while three of the remaining four are new. In addition, magnetic observations were made in conjunction with gravitational surveys which were carried on with the torsion-balance in the vicinity of two known faults near Ottawa.

26. *International Electrical Congress, Paris, 1932*—There is being organized under the auspices of the International Electrotechnical Commission, by a number of French scientific and technical societies, an International Electrical Congress which is to meet in Paris in 1932, and which will furnish an occasion for summing up the work of the half-century which has elapsed since the first International Electricity Congress took place in Paris in 1881. At this first congress a coherent and logical system of units was established which has since been employed by electricians the world over. At the 1932 congress the principal questions concerning scientific and technical electricity will be set forth and discussed. The work of the congress will be divided into twelve sections, three of which will be devoted to: Radioelectricity, phenomena of high frequency, and radiocommunications (Section 9); radiology, electrophysiology (Section 10); and atmospheric electricity and terrestrial magnetism (Section 11). The address of the Committee of Organization, of which M. Paul Janet is president, is 134 Boulevard Haussmann, Paris (VIII^{e}), France.

27. *Ball-lightning*—In the hope of obtaining new light on the mysterious phenomenon known as ball-lightning, Dr. W. J. Humphreys, meteorological physicist of the United States Weather Bureau, desires to receive reports from all persons who have observed it. Ball-lightning is quite unlike the ordinary, almost instantaneous electrical discharge that constitutes ordinary lightning. It is a slow, long-continuing discharge that floats through the air or runs along the ground in the shape of a ball, or sometimes the shape of a pear. The color varies from red through blue to dazzling white. These glowing balls often enter houses, coming down the chimney or entering through a window, door, or even a crack. They float or glide around, sometimes with a fluttering or crackling sound, but seldom do any harm. Dr. Humphreys has drawn up the following list of questions to assist in the description of the phenomenon:

Who saw it? Names and addresses of all witnesses should be given. Where and when was it seen? Location, date, and time of day should be as exact as possible. Did it come at the beginning, middle, or end of the storm? Did it occur indoors or out? If indoors, how did it get in and how did it leave? Was there one ball, or were there more than one? How long did it last? What were its size, shape, and color? Was its outline sharp or fuzzy? Did it make any noise? Did it leave an odor? Did it move or stand still? If moving, did it go with the wind or against it? Was its movement vertical, horizontal, or at an angle? How fast did it move? Was its movement smooth or in jerks? What were its effects?

It is desired that observers of ball-lightning send their answers to Dr. W. J. Humphreys, United States Weather Bureau, Washington, D. C., U. S. A. He is especially hopeful that someone may succeed in obtaining a photograph of a ball-lightning discharge, since no really authenticated photograph of this kind has ever been taken.

AURORAL OBSERVATIONS AND MAGNETIC CONDITIONS AT THE SITKA MAGNETIC OBSERVATORY, JULY 1929 TO JUNE 1930[1]

By Franklin P. Ulrich

This paper is a continuation of the reports,[2] begun in 1923, of the investigation concerning the relation between aurora, the Earth's magnetic field, and radio reception. The investigation of the Earth's magnetic field and its relation to radio reception was discontinued with the report for last year because of the lack of proper sensitive instruments and because this investigation is being taken up elsewhere in a more detailed manner than was possible at this Observatory.

The work for this year is divided into two parts: (*a*) Auroral observations with a comparison of the Earth's magnetic field, and (*b*) the auroral frequency with a comparison of the Earth's magnetic condition. Auroral observations were made only once during this year, due primarily to the absence of the observer from the Observatory during November and December.

Instruments and methods—The instruments and methods as outlined in the report for 1923–24 were used during these observations.

Auroral observations—The following is the auroral log for April 30, 1930, the times being standard 135th west meridian time. Observed elevations (el.) and azimuths (az.) are in degrees; abbreviations *D*, *H*, and *Z* are used for the magnetic elements, and dec. and inc. for decreasing and increasing, respectively.

22:46—Pale yellow glow of brightness 3 up to el. 30 from az. 175 to 260; pale yellow band of brightness 8 along sky-line and up to el. 8 from az. 206 to 215. (*D* dec. to 22:46 and inc. to 22:50, dec. to 22:57; *H* dec. from 22:44 to 22:46, inc. to 22:47; *Z* dec. from 22:40 to 22:57.)

22:48—Patches of pale yellow rays of brightness 6 between az. 198 and 253 extending from about 5 degrees above sky-line to el. 35. (*H* inc. from 22:47 to 22:55.)

22:49—Rays gradually disappearing.

22:50—At this time a ray of brightness 8 was visible for a short period at az. 230 from el. 30 to 70 with fainter rays up to el. 70 on each side of this bright ray.

22:53—Small group of rays of brightness 8 center around az. 210 and just above sky-line; larger groups of rays of brightness 10 between az. 225 to 235 and just above sky-line; rest of sky clear except at az. 230 faint rays extend up to el. 60.

22:56—Few groups of rays of brightness 4 between az. 170 and 188 and just above sky-line. (*H* inc. from 22:55 to 22:56, dec. to 22:59.)

22:58—Sharp bright rays around az. 222 between el. 30 and 60; fainter groups between az. 200 and 225 and along sky-line. (*D* inc. from 22:57 to 23:01; *Z* inc. from 22:57 to 23:00.)

23:01—Rays gone, only faint diffused aurora along north sky-line. (*D* dec. from 23:01 to 23:06; *H* inc. from 22:59 to 23:03; *Z* dec. from 23:00 to 23:03.)

23:02—Group of bright rays at az. 238 along sky-line and up 5 degrees above sky-line.

[1] Published by permission R. S. Patton, Director, United States Coast and Geodetic Survey.

[2] For previous reports see Terr. Mag., **30**, 150-151 (1925), **33**, 162-165 (1928), and **34**, 301-302 (1929).

23:03—Rays gone. (H dec. from 23:03 to 23:04; Z inc. from 23:03 to 23:04.)

23:04—Fainter groups of rays of brightness 4 come and go between az. 180 and az. 195 and along sky-line. (H inc. from 23:04 to 23:04.5 and dec. to 23:10; Z dec. from 23:04 to 23:12.)

23:07—Sharp ray at az. 154 between el. 25 and 50 with fainter rays between same elevations over to az. 188; group of rays at az. 203 and at same elevation, all rays pointing towards the zenith. (D inc. from 23:06 to 23:11.)

23:10—Rays gone, only faint patches of diffused aurora from az. 155 to az. 280, and this aurora is very faint in the east. (H inc. from 23:10 to 23:11, dec. to 23:12, inc. to 23:13, and dec. to 23:16.)

23:14—Aurora of brightness 3 in the form of arcs with the ends pointing eastward at az. 203 and 222; appearance like light clouds. (D dec. from 23:11 to 23:12 and inc. to 23:27; Z inc. from 23:12 to 23:33.)

23:18—Only faint patches of diffused aurora in the north sky, which come and go slowly. (H inc. from 23:16 to 23:19, dec. to 23:20, inc. to 23:24, dec. to 23:25, and inc. to 23:30.)

23:21—Aurora practically gone, so discontinued observations.

Auroral frequency.—The following record is for Sitka and shows the frequency of aurora on clear and partly cloudy nights. Observations were taken up to the 23^h and reports after that time were only casual. The number in parentheses indicates the magnetic character for the time observed.

1929, Sept. 7—Clear; no aurora; (0). Sept. 16—Partly cloudy; no aurora; (0). Sept. 17—Partly cloudy; no aurora; (0). Sept. 21—Partly cloudy; few rays from 19:30 to 19:35 and from 20:05 to 20:07; cloudy after 21^h; (2). Sept. 22—Clear to 22^h, then partly cloudy; no aurora; (0). Sept. 23—Partly cloudy; no aurora; (0). Sept. 24—Partly cloudy 23^h to 24^h; no aurora; (0).

1929, Oct. 7—Clear; no aurora; (1). Oct. 19—Partly cloudy; no aurora; (0). Oct. 20—Clear; no aurora; (0).

1929, Nov. 9—Clear; no aurora; (0). Nov. 18—Partly cloudy; no aurora; (0). Nov. 21—Partly cloudy; no aurora; (0). Nov. 29—Clear; no aurora; (0).

1929, Dec. 4—Partly cloudy; aurora 18^h to 22^h with rays at irregular intervals; (2). Dec. 5—Partly cloudy; aurora reported at 22:30; (1). Dec. 6—Clear; no aurora; (0). Dec. 7—Clear; no aurora; (1). Dec. 8, 9—Clear; no aurora; (0). Dec. 10—Clear; faint rays reported seen at 21^h; (1). Dec. 11—Clear; no aurora; (1). Dec. 12—Clear; faint arch seen to the north-northeast for only a few minutes at about 22:10; (1) Dec. 13, 14, 15, 16, 18—Clear; no aurora; (0). Dec. 22—Clear; no aurora; (1). Dec. 24—Clear 21^h to 24^h; no aurora; (0). Dec. 31—Clear; no aurora; (0).

1930, Jan. 3—Pale glow with few rays along sky-line between mountains; aurora reported on morning of Jan. 4; (1). Jan. 4—Pale glow only along sky-line; (1). Jan. 5—Bright aurora at 6:30; (2). No aurora in evening till 23^h; (1). Jan. 6—Aurora along sky-line at 6:30; (2). Jan. 7—Clear; no aurora; (1). Jan. 8—Faint aurora along sky-line with bands above at 6:30; (1). Jan. 11, 12, 13, 14, 15, 16, 17—Clear to 24^h; no aurora; (0). Jan. 18—Clear; no aurora; (1). Jan. 19, 20, 21, 22, 23, 24, 25, 26, 27—Clear; no aurora; (0). Jan. 28—Clear; no aurora; (1).

1930, Feb. 26—Clear; no aurora; (0). Feb. 28—Partly cloudy; pale aurora along sky-line; (1).

1930, Mar. 1—Partly cloudy; pale glow along north sky-line; (1). Mar. 18—Clear; pale steady glow in north sky at 20^h, reaching up to el. 30; (1). Mar. 19—Partly cloudy; pale glow along north sky-line; (1). Mar. 29—Clear; no aurora; (1).

1930, April 6—Clear; no aurora; (1). Aurora reported late at night; (1). April 7—Clear; no aurora; (2). April 12—Partly cloudy; no aurora; (1). April 14—Partly

cloudy; aurora through clouds; (1). April 15—Clear; pale glow along sky-line; (1). April 16—Clear; rays between mountains and above; auroral observations from 22:40 to 23:21; (1). April 18—Clear; no aurora; (0). April 19—Clear; beautiful aurora all night (observer ill and unable to take observations); (2 after 20:30).

Summary—During the observation of aurora no pulsations or draperies were observed. Rays were observed eight times, and during these eight times D was increasing and decreasing four times each, H was increasing five times and decreasing three times, Z was increasing two times and decreasing four times. For this year almost the same ratios hold true for diffused aurora. Diffused aurora was observed thirteen times, and during these thirteen times D was increasing seven times and decreasing six times, H was increasing eight times and decreasing five times, Z was increasing four times and decreasing nine times.

Auroral frequency—From September 7, 1929, to April 19, 1930, there were 69 clear or partly cloudy evenings, so that the aurora could have been seen if visible. In addition to these 69 times, aurora were reported two times to the observer as occurring in the early morning hours. Aurora are visible nineteen times, and during the appearance of the aurora, in each instance, the magnetic elements were disturbed. The magnetic character was (1) for fifteen of these times and (2) for the other four times. During the year no bright aurora occurred on a (1) day, but all occurred on a (2) day.

There were fifty-two times that no aurora were observed, and of these fifty-two times forty were during (0) days, eleven were during (1) days, and one was during a (2) day. This conforms to the former observations that were taken for Sitka only, namely, that there are magnetically disturbed days on which no aurora occur, and that when aurora occur the magnetic elements are disturbed. This is the first time that no aurora was observed during a (2) day.

Sitka Magnetic Observatory,
Sitka, Alaska

NOTES

(See also pages 170 and 238)

28. *Errata and corrections*—The author having made some corrections in computations, and there being a few errata in tables and text on pages 136-138 of the June number of the JOURNAL, there is supplied with this number a corrected copy of pages 135–138, which subscribers are requested to substitute for the corresponding pages in the June number.

The last two lines on page 109 of the last number of the JOURNAL should read "which have no diurnal variation" instead of "which have diurnal variation." The address should be "Telegrafverkets Provningsanstalt" instead of "Telegrafverkets Provninganstalt." Also footnote 9, page 108, should read "H. Hyyryläinen, etc." instead of "H. Hyyrylaïnen, etc."

29. *Cosmic-ray investigations in Colorado*—Prof. *Arthur H. Compton*, of the University of Chicago, will continue during September his investigations of the penetrating power and effects of cosmic rays in the mountains and canyons of Colorado. Dr. *Joyce C. Searns*, professor of physics at the University of Denver, is in charge of the Expedition which includes several selected students from the two above-named universities by which the Expedition is sponsored. Members of the Expedition will climb Mount Evans, one of the highest peaks in Colorado and take measurements at that altitude. It is also proposed to make determinations in Grand Lake (8,389 feet above sea-level).

30. *Personalia*—Prof. Dr. *Adolf Schmidt*, formerly of the Prussian Meteorological Institute at Potsdam, and for whom the new Adolf Schmidt Observatory at Niemegk has been named, observed his seventy-first birthday on July 23, 1931.

Prof. Dr. *Albert Wigand* has been chosen Rector of the Hamburg University for the year beginning October 1, 1931.

Mr. *R. Glenn Madill*, of the Dominion Observatory, Ottawa, left in June to make magnetic observations at stations previously established along the Mackenzie River. If time permits he will establish new stations at Fort Liard and Herschel Island.

Dr. *Knud Rasmussen* will make a trip this year along the eastern coast of Greenland from Cape Farewell to Angmagssalik and return, in the course of which a series of magnetic measurements will be undertaken with the view of securing magnetic data in this region where no observations have yet been made.

Lincoln Ellsworth took part in the trial polar flight of the *Graf Zeppelin* under the auspices of *Aeroarctic* last July as an arctic expert in nagivation and as a representative of the American Geographical Society.

Mr. *J. M. Stagg*, of the Meteorological Office, London, visited Fort Rae, Canada, in July, to examine a possible site and make arrangements for the accommodation and equipment of the British party which it is planned will occupy this station for a full program of meteorological, magnetic, and auroral work during the Polar Year 1932–1933. During the period July 25 to 31, he was in Washington, D. C., where he visited the Department of Terrestrial Magnetism, Weather Bureau, Cheltenham Magnetic Observatory, and other scientific organizations, familiarizing himself with their methods and work.

Mr. *J. W. Green*, magnetician of the Department of Terrestrial Magnetism, accompanied by Mr. *Earl Hanson*, observer, sailed on August 5, 1931, from New York for Havana, Cuba, en route to the West Indies and South American countries where a series of magnetic stations will be reoccupied. Messrs. Green and Hanson will work together until the latter has acquired sufficient experience in field-methods to proceed alone. The chief purpose of this expedition is to secure definite and reliable information as to the changes in the magnetic field which have taken place at selected stations since previous occupations, thus obtaining data from which the best possible distribution of secular rates and periodic changes of any of the elements may be derived.

Prof. *E. Mathias* has retired as Director of the Observatoire du Puy de Dôme and professor on the Faculty of Sciences at Clermont-Ferrand. He will however retain the secretaryship of the French Section of Terrestrial Magnetism and Electricity.

ON OBSERVATIONS OF MAGNETIC ANOMALIES WITH A VARIOMETER

By J. G. Koenigsberger

Abstract—The accuracy of determinations for magnetic anomalies in horizontal intensity, H, and vertical intensity, Z, using the author's variometer, is now as good as that obtained by absolute measurements. The variometer can be used accurately without resetting for determinations on lines as long as 300 kilometers in the north-south direction. The question as to whether local anomalies may be affected by secular variations is discussed theoretically. An attempt to check the theory developed using previous observations of intensity gives no definite conclusions; absolute measurements of inclination with the dip-needle are not of sufficient accuracy to give a reliable test. In the study of a deep-seated regional anomaly and in the preparation of land magnetic charts, it is found best to discard all values at stations where the adjacent rocks have differences of susceptibility of more than 2×10^{-4}.

§ 1. *Instrument*[1]—The instrument (see Fig. *A*) used for the author's measurements referred to below was constructed by H. Elbs, Freiburg i.B., according to the author's directions, for the determination of the variation of the magnetic vector from its three elements Z, H, and D. It is patterned after a vertical-intensity variometer,[2] with fiber-suspension

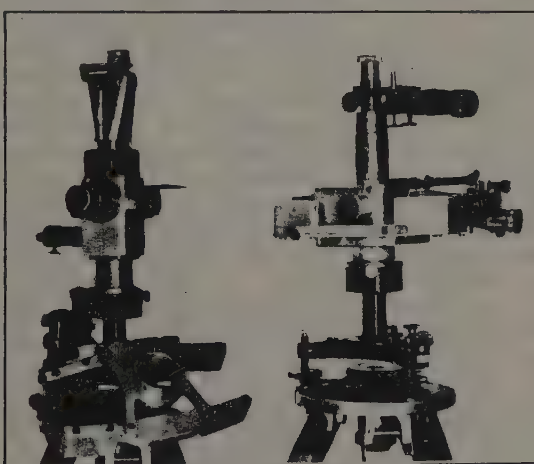


Fig. *A*

for the magnet. The essential feature, the fiber-suspension, has been improved to secure invariability of tension and clamping—two critical conditions for precision of measurements. Thus a displacement a few hundredths of a millimeter of the point where the fiber is attached to the magnet produces a zero-point displacement corresponding to from 2 to 6γ. Various other experimental apparatus which the author has

[1] See J. Koenigsberger, Messung lokaler erdmagnetischer Anomalien, Beitr. Geophysik, 23, No. 3, 264-267 (1929). [The author is indebted to H. D. Harradon of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington for the translation of this description.]

[2] Zs. Geophysik, 1, 237 (1924).

had the opportunity of testing—in which, for example, the fiber was fixed in a very sharp, narrow, wedge-shaped groove—showed an improvement as compared with the earlier construction, but were found inadequate for precise measurements when subjected to difficult conditions of transportation in the field. Thus the zero-point was frequently found to change by as much as $\pm 15\gamma$. By means of the simple device shown in Figure *B*, it was possible to maintain for two years exact clamping of the fiber during measurements.[3] With this arrangement[4] values to

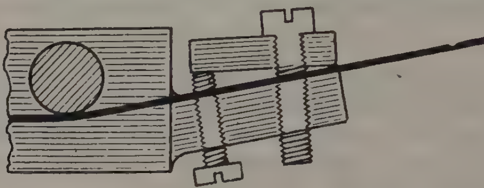


FIG. *B*

within $\pm 3\gamma$ may be obtained in repeat-observations after field use as shown by control-observations made with a second instrument remaining in place. Another improvement is effected by magnetically protecting the magnet, constancy of which is assumed, immediately following each series of observations by soft-iron shields which may be placed over the copper casing. Before this improvement was made it was found that during transportation on electric trams or railways and near electric power-lines, irregular changes[4] took place. The variometer is further adapted to measure horizontal intensity and declination by making it reversible with the aid of cones to permit placing the suspending fiber vertical instead of horizontal. The horizontal intensity is compensated by a conical attachment with four small magnets, which may be fixed to the conical jacket in grooves; these magnets are adjustable in the direction of their longitudinal axes and, when once set for a particular region, may be clamped in position. During observations the instrument is so oriented that the longitudinal axis of the magnet is in east-west direction with approximate compensation in intensity. Thus at any station the magnet-needle shows a definite position on the scale. The calibration is determined, as in the case of the vertical intensity, by means of a calibrated auxiliary magnet set at a determined distance. The temperature-coefficient must also be determined very accurately; it is smaller than in the case of the vertical intensity.

The local variation of declination is determined by means of a telescope, which is attached at the top of the instrument, also with cone and grooves (see Fig. *A*, right). The telescope may be turned and clamped, its axis is adjustable, and its scale may be centered. Readings made on Sun or mark, at a considerable distance with reference to the two stations, or on preceding and following stations, and the change of the angle of the magnet at the two stations with reference to the line of sight is measured. The magnet is then always set on the same scale-division in the middle of the scale of the magnet-telescope. The position

[3] Two other similarly constructed vertical-intensity variometers with fiber-suspensions have maintained equal accuracy for a longer series of magnetic measurements by another institute according to information kindly communicated by the Director.

[4] Compare Zs. Geophysik, **4**, 236 (1928).

of the point sighted on in the sighting-telescope is read on a fixed scale in the ocular. Variations in vertical intensity and horizontal intensity as great as 1,500γ are compensated for by auxiliary magnets which can be clamped to an adjustable graduated bar. The susceptibility is determined by a plate on the copper tube (see Fig. *A*).

The variometer may also be used for the absolute determination of the horizontal intensity by replacing the attachment carrying the four magnets with a calibrated double Helmholtz coil and comparing the potential differences of the current through a constant resistance with a standard cell in the usual way. When necessary for control or for other reasons, the declination may be measured by making sun-observations for azimuth; this is more difficult and gives less accuracy than the relative measurements. Absolute determinations of vertical intensity could also be made with this variometer by the addition of special arrangements, but those so far devised would be inconvenient in field-use.

§ 2. *Accuracy of magnetic variometer-observations*—The variometer for the determination of magnetic anomalies as indicated above has been found to have no sudden changes in its zero-point and not to be irregularly affected by rapid change of temperature. When the temperature-difference of variometer and air is more than about 5°, it is necessary to wait about 3 to 5 minutes so that the thermometer may take the same temperature as the magnet. The temperature-coefficient, which must be accurately determined, for an increase of one degree Centigrade is, for the best grade of magnet steel now available and as used in my variometers, generally $-$ 10.1γ for the vertical intensity, *Z*, and + 8.2γ for the horizontal intensity, *H*. The zero-point of the variometer has remained unchanged for many weeks and months. The diurnal variation and magnetic disturbances give rise to some uncertainty, as no recording observatory is situated in south Germany, where the instrument was used. Therefore, observations on days of large magnetic disturbance, as determined subsequently from the records of the magnetic observatory at Seddin, had to be discarded. The average diurnal-variation for Freiburg was used for approximate corrections to mean of day for stations near Freiburg. The other data given here have not been corrected for the diurnal variation. The accuracy of the variometer-observations for *H* and *Z* can be seen by typical data showing readings of instrument at base-stations before and after trips in the field. (*I*) At station Goeschenen *I* at $16^h\ 05^m$ on August 21, 1929, readings were 0 for *Z* and 0 for *H*; observations were then made on the 30-kilometer line from Andernatt to Disentis; on the return to Goeschenen *II* at $7^h\ 40^m$ on August 25, 1929, the readings were + 15γ for *Z* and + 5γ for *H*. (*II*) At station Goeschenen *I* (Switzerland) at $10^h\ 55^m$ on August 25, 1929, readings for *Z* and *H* were both zero; after observations during three days along the Gotthard Railway to Bellinzona and return the readings at the base-station *I* at $7^h\ 15^m$ on August 28, 1929, were $-$ 3γ for *Z* and + 12γ for H. (*III*) At station Freiburg *I* (Baden, Germany) at $15^h\ 10^m$ on June 23, 1930, the readings were 0 for *Z* and 0 for *H*; after various railway trips and observations upon return to the base-station Freiburg *I* they were at $12^h\ 50^m$ on July 9, 1930, $-$ 9γ for *Z* and $-$ 24γ for *H*. (*IV*) After a ten-day interval of travel and observation from Freiburg *I* where the readings were 0 for *Z* and 0 for *H* at $14^h\ 20^m$ on November 17, 1930, they were + 3γ

for Z and -5γ for H at $16^h\ 30^m$ on November 27, 1930. The range of the instrument is such that generally changes in values of Z and H may be observed without altering the zero-setting on north-south lines as long as 300 kilometers and of even much greater length for east-west lines. The time required for accurate determinations of Z and H is from 10 to 20 minutes for both elements.

§ 3. *Local anomalies and secular variation*—It is doubtful whether local magnetic anomalies are affected by the secular variation. Dr. C. A. Heiland has mentioned this question and Prof. A. W. Lane has inquired regarding it. Where remanent magnetization of rocks is the principal cause of the anomaly, the secular changes in a region of magnetic anomaly must be approximately equal to the ideal secular changes of the normal field computed on the basis of distances between stations, the remanent magnetism remaining unchanged. Should induced magnetism have an effect, this would not be true.

Let $(Z)_1$ be the observed value of Z at a station 1. This value is the sum of the value due to the normal inner and outer field of the Earth, designated as $(Z_0)_1$, of the resultant effect of the remanent magnetism of the magnetized rock, designated as $\sum_i (Z_r^i)_1$, and of the first approximation of the effect arising from the induction of the normal field $(Z_0)_1$ on all rock of susceptibility K, designated as $\left(\sum_i a_i K_i (Z_0)\right)_1$, written as $\Sigma a K Z_0$. Using the corresponding notation for a second station 2, we would have to express the difference between observed values at the two stations at the epoch of observation, t

$$(Z)_1 - (Z)_2 = \triangle_{12} Z = (Z_1)_0 - (Z_2)_0 + \Sigma(Z_r)_1 - \Sigma(Z_r)_2 + (Z_1)_0 \Sigma a_1 K_1 - (Z_2)_0 \Sigma a_2 K_2 \qquad (1)$$

A smiliar equation may be written for a second epoch of observation, t', the prime mark indicating corresponding notations. Representing the difference of the values due to the normal field at the two epochs $[(Z_1)_0 - (Z_2)_0]$ as $(\triangle_{12} Z)_0$ we would have

$$[\triangle_{12} Z' - (\triangle_{12} Z')_0] - [\triangle_{12} Z - (\triangle_{12} Z)_0] = (Z'_1 - Z_1)_0 \Sigma a_1 K_1 + (Z'_2 - Z_2)_0 \Sigma a_2 K_2 \qquad (2)$$

$\triangle_{12} Z$ and $\triangle_{12} Z'$ are the local differences observed at the two epochs. The values for $(Z'_1 - Z_1)_0$ and $(Z^1{}_2 - Z_2)_0$ may be evaluated approximately from world isomagnetic charts for the two epochs. If the remanent magnetism of the rock be strong and if the induced magnetism has little influence, $\Sigma a K$ approaching 0, the observed change $(\triangle_{12} Z' - \triangle_{12} Z)$ must be approximately equal to the average ideal secular change $[(\triangle_{12} Z')_0 - (\triangle_{12} Z)_0]$. The same conclusions may be drawn with approximation for horizontal intensity.

Experiments show that practically the remanent magnetism of most rocks disappears at 590° C (critical temperature of magnetite), and for a coercive force of 0.1 CGS unit at about 550° for ordinary pressure. Because of temperature, etc., remanent magnetism of rocks like those at surface probably disappears practically at 15-20 km, provided the pressure does not affect greatly the magnetic critical point of magnetite in the rocks. If this be true, large and deep-seated anomalies extending over more than 50 to 100 km are due to induced magnetism. Therefore, from the above formulae differences between two places affected by so

large an anomaly should not be equal to the average secular-change of the region, if magnetite is the cause of their susceptibility.

It is difficult to test this conclusion. Nippoldt compared the value of Z for 1921 for the great regional European anomaly with that calculated for 1885 by Bauer and found no great change. However, the terrestrial dipole change for this period is also small (6 per cent). To test the formulae given above the author made some measurements of H and Z during 1929–30 at the same stations where Batelli (B.) observed in 1892 or van Rijckevorsel and van Bemmelen (v.R. v.B.) observed in 1895 and where Nippoldt observed in 1906 (for literature see "Archiv des Erdmagnetismus," Heft 6, Berlin, 1927). The average secular-changes between 1895 and 1921 in the region between 47° and 48° north latitude in 8° east, per 100 km, as determined using the spherical harmonic analyses of Ad. Schmidt for 1885 and of L. A. Bauer for 1922, are 670(1921) − 570(1895) = +100γ or +16 per cent in Z and 410(1921) − 420(1895) = −10γ or −2.5 per cent in H. The secular variation in H for this period is therefore negligible. The isomagnetic map in the Steinhaus Atlas (1885) and the European isomagnetic chart by Nippoldt (1922) give 500 − 400 = +100γ or +22 against 16 per cent in Z and 500 − 480 = +20γ or +4 against −2.5 per cent in H. The data first given seem better fitted for this purpose. On the 271-kilometer north-south line from Freiburg to Chiasso the average observed value of $(\triangle_{12}Z)_0$ in 1929-30 was about 600γ, and thus its value in 1892 was about 500γ—these are taken as ideal normal differences per 100 km. The difference between the observed value and the normal value, $[\triangle_{12}Z - (\triangle_{12}Z)_0] = D_{oi}$, is due to the local anomalies and to errors of observations. Its value for line Olten to Lugano for Z (see Table 1) was −95γ in 1892 (B.) and −15γ in 1930 (K). Therefore, the left side of equation (2) is −80, thus not equal to zero. For H the values of D_{oi} were +10γ in 1892 and +15γ in 1929; thus their difference being zero, the influence of induced magnetism of the local anomalies is small. Other results for secular variation at different epochs on several lines are shown in Table 1.

TABLE 1—*Values D_{oi} of magnetic vertical intensity and horizontal intensity*

Line	Epoch	Z	H	Epoch	Z	H
		γ	γ		γ	γ
Basel-Olten	1892B	+140	+10	1929	+15	+15
Goldau-Goeschenen	1892B	+ 65	+85	1929	+85	+35
Olten-Goeschenen	1892B	− 75	+ 5	1929	+15	+25
Flüelen-Goeschenen	1892B	− 45	+50	1929	+30	−25
Olten-Lugano	1892B	− 95	−80	1930	−15	−20
Schönenwerth-Meggen	1895R	−150	−90	1929	+60	−40
Meggen-Seewen	1895R	+ 39	+29	1929	−45	−15
Meggen-Amsteg	1895R	− 20	+25	1929	+25	−10
Arth-Seewen	1895R	− 70	+ 8	1929	+60	+10

The difference of D_{oi}-values in H for the periods 1892 to 1929 or 1895 to 1929 is very small, as should be expected because of the small secular variation. The differences in D_{oi} and H determined from the observations of van Rijckevorsel and van Bemmelen and those of the author are astonishingly small when it is recalled that the former made no corrections for diurnal variation. Those from the observations of Batelli, while sometimes larger, are for H mostly within the limit of

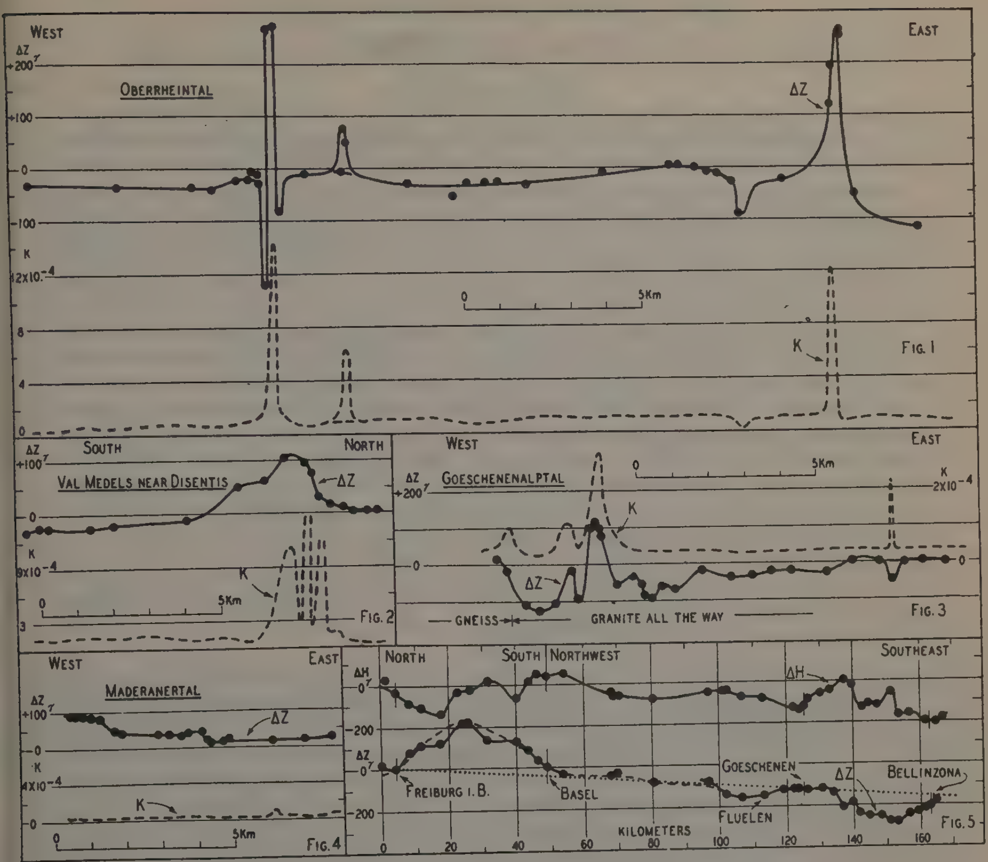
errors and diurnal variations. The determinations of H have always been exact, and are affected only by the diurnal variations. Since H is more sensitive as a measure of local inhomogeneities than Z and as it is often not possible to relocate stations exactly, the author has studied the local inhomogeneity at the various stations. He found that Airolo was the only station of Batelli with very strong local inhomogeneity.

For Z the larger ideal secular-variation between 1892 and 1929 would lead one to expect time-differences in the local anomalies. It is possible that the differences of the disturbed magnetic field between two stations with greater separation would show more change than for two stations with lesser separation. For greater distances deep-situated anomalies come into effect, and therefore the remanent magnetism is probably of lesser influence than for anomalies caused by rocks nearer the surface and therefore colder. The data given in Table 1 seem to point in this direction. On the other hand, the precision of the older observations of Z seem to me sufficient to permit a definite conclusion, since previous observers have computed Z from observations of inclination, and dip-needle measurements are sometimes not very accurate.[5] For example, the observations of Batelli give the difference between Goeschenen and Gotthardospiz, two very normal (see § 4) stations, only 10 km from another, -292γ, whereas in 1929 the author only found about $+25\gamma$.

§ 4. *Elimination of superficial local magnetic influences*—Magnetic anomalies result from local and regional influences of rocks having different susceptibility and remanent magnetization and situated at different depths. In the investigation of such anomalies the first step is to eliminate the purely local and superficial influences. This can be done by determining at each station the susceptibility of neighboring rocks. That these may be responsible for many of the larger effects can be seen by inspection of the graphs (Fig. 1 to 4) giving Z-profiles and values of the susceptibility, K, of the neighboring rocks for the Alpine region of Switzerland where the rocks are exposed, and which evidently are the cause of many of the local magnetic anomalies. Exceptionally great differences in the susceptibilities and in the values of the magnetic field were found at Airolo and in the Urserental. Without knowing the limits and depth of rock with susceptibility K bedded in environing rocks with susceptibility K_0, it is not possible to calculate exactly the effect $\triangle Z$, which for a very flat horizontal disc, except near the border, will be zero or for a very elongated ellipsoid, $4\pi(K-K_0)$. With some probability $\triangle Z = KZ/(1+4\pi K/3)$ may be taken as an average value.

For the analysis of a regional deep-situated anomaly the author regards it the best practice to disregard all values at places with a difference of the susceptibility of adjacent rocks, $(K-K_0)$, greater than, or equal to, 5×10^{-4}. Based on this assumption, a magnetic profile may be drawn such as Figure 5, which reproduces a preliminary graph prepared before finally corrected and new data (see Table 1) had been compiled for a line through the Black Forest (Baden, Germany), the Swiss Jura, and the Swiss Alps along the line Gotthard to Lago Maggiore (Italy). The additional observations along the general course of this line, and an extension to Lago di Lugano and Chiasso (Italy), in

[5] D. L. Hazard, Directions for magnetic measurements, Washington, D. C., Dept. Comm., U. S. Coast Geod. Surv., Serial No. 166, 1921, and H. W. Fisk, Land magnetic observations, 1921–1926, Researches of the Department of Terrestrial Magnetism of the Carnegie Institution, Volume VI, Washington, D. C., Carnegie Inst., Pub. No. 175 (Vol. VI), 1927.



FIGS. 1 TO 5

the revised curvatures of the profiles for differences of H and Z against the normal values, indicate the depth of the center of the disturbing rock 15-20 km from Freiburg to be about 7 to 12 km for the principal anomaly and that of the secondary anomaly in the same region about 5 km. At 100 and 150 km from Freiburg the anomaly has a depth of center of about 5 km, and at 200 km of more than 10 km. Some very weak and shallow maxima are indicated at kilometers 163 and 190. The deepest disturbance seems more probably caused by intrusive basic rocks than tectonics. The same or a similar anomaly was detected on the other side of the Rhine (Alsatia, France) by J. Jung and C. Alexanian, who reported on it in Annales de l'Office national des combustibles liquides for 1931 (pp. 43-58).

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REVIEWS AND ABSTRACTS

(See also pages 253 and 262)

Stöckl, K.: *Der Magnetismus bei Kepler.* Kepler-Festschrift, Teil I, herausgegeben von Prof. Dr. Karl Stöckl. Regensburg, Bericht des Naturwissenschaftlichen Vereins zu Regenburg, 19. Heft für die Jahre 1928/30 (264-278).

This brief essay is one of the contributions to the memorial volume published on the occasion of the 300th anniversary of the death of the great astronomer Johannis Kepler (1571–1630) and contains much information of interest to students of the early history of terrestrial magnetism. It deals with Kepler's work and speculations in the field of magnetism.

The epoch-making voyages made by the mariners of Spain and other nations of Western Europe in the 15th and 16th centuries had disclosed the fact that the compass-needle rarely points due north, as previously supposed, and had led to the discovery of the magnetic declination. As the accurate determination of this angle was of prime importance to nagivation, no little attention was being given to the problem. To this matter Kepler also turned his attention and after introducing improvements to the liquid-compass as already known to the Chinese and Arabians, in order to eliminate as far as possible the error due to friction, he measured the declination in 1599 at Graz and found it to be somewhat less than 6° east, and later at Prague 5° and 6° east. The importance of these experiments has been appraised by S. Günther in the following words: "Kepler produced a declinometer not only suitable for quantitative observation, but also for actual numerical determination at a time when Gilbert's book with its many innovations had not yet been published."

It was likewise believed at the time that a very simple relation existed between the geographic longitude and the magnetic declination so that the one might be derived from the other. Kepler was also at first of this opinion and devoted some attention to the problem, but was later obliged to abandon the idea when he found that the declination as determined at various points did not agree with his computed values, and he suggested several possible theories to account for the discrepancies. In his work entitled "Somnium," which was published after his death, he admits that Gilbert's investigations and many carefully conducted experiments had shown the futility of this method and states that "Besides the Pole there is no definite point on the Earth's surface towards which the magnetic needle points, but there are mountainous elevations everywhere which influence the needle in a slight degree," indicating that Kepler was aware of local disturbances.

At the beginning of the 16th century it was still generally thought that the force which attracted the north-seeking end of the magnetic needle resided in the Pole-Star, an idea which has furnished both before and since a favorite theme for the poets, as, for example, in the Divina Commedia of Dante which is the epitome of the scientific knowledge of his time (*cf.* Par. xii, 28ff.). The great cartographer Mercator, who was also a student of terrestrial magnetism and to whom is attributed the concept of the Earth's magnetic poles, is said to have been among the first to reject this fallacy and to seek the source of the Earth's magnetism in the Earth itself. In order to investigate this question, Kepler constructed what must indeed be termed an inclinometer with graduated vertical circle and suspended magnet turning about a horizontal axis, and succeeded not only in verifying the theory, but also in showing that the vertical circle must be set up in the magnetic meridian.

In the second part of his paper, the author shows how Kepler's knowledge of attractive forces as gained from his magnetic investigations was gradually extended to embrace the Sun and planets, thus displacing the ancient idea of a soul (anima) as the source of motion, and substituting in its place the concept of force (vis), and so paved the way to the discovery of the laws that govern the movements of the planets and to the foundation of physical astronomy.

H. D. Harradon

[From *Terrestrial Magnetism and Atmospheric Electricity*, September, 1931]

FINAL RELATIVE SUNSPOT-NUMBERS FOR 1930

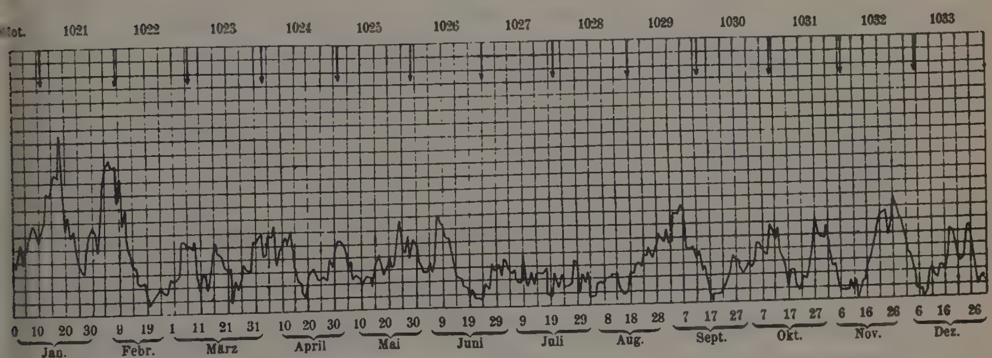
By W. Brunner

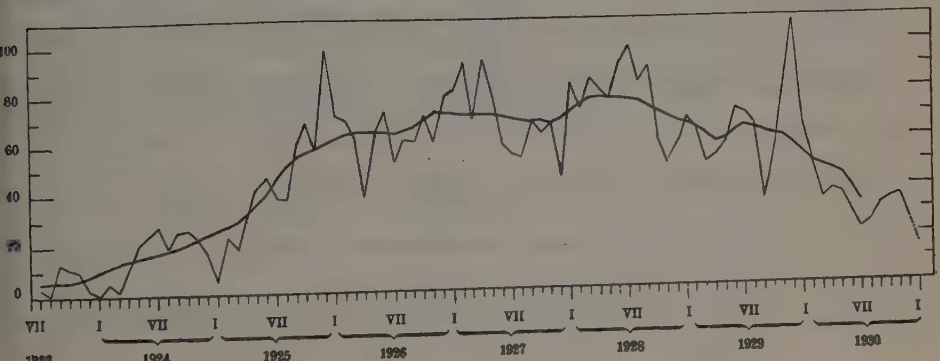
The following tables contain the final relative sunspot-numbers for 1930, for the whole disc of the Sun, based on observations made at the Zurich Observatory, supplemented by series furnished by other co-operating observatories for days (indicated by asterisks) where no observations were possible at Zurich.

Table 2 gives the yearly mean of the relative numbers, R, since the last minimum 1923 and the number of days without spots.

Table 2—*Yearly means of relative sunspot-numbers, R*

Year	R	Increase	No. spotless days
1923	5.8	......	200
1924	16.7	+10.9	116
1925	44.3	+27.6	29
1926	63.9	+19.6	2
1927	69.0	+ 5.1	0
1928	77.8	+ 8.8	0
1929	65.0	−12.5	0
1930	35.7	−29.3	3





Figs. 1 and 2

Table 1—*Final relative sunspot-numbers for the whole disc of the Sun for 1930*

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	36	47[d]	23[a]	56[b]	52	31	22[a]	17	56[d]	26	57	45[a]
2	41[d]	73	24	59[d]	52[a]	28	36	23	46[a]	30[a]	41	35
3	55	98[a]	28	41	50	28[a]	35	7	*M*48[c]	26	25	33
4	38	*M*111[c]	54	42*	41	*M*34[c]	28	7	68[ad]	30[d]	26	20
5	49	117[a]	55	*E* 58[c]	*E* 30[c]	27	26	7	66	44*	16	8
6	55[d]	110	50	57	37	*E* 34[ac]	28	17[d]	73	43	8	7
7	62[a]	111*	50[b]	65[b]	24[b]	*E* 70[c]	18	17	70	39	8	7
8	68[a]	82[a]	49[b]	35	26	65[a]	18	16	41[a]	37	8	0*
9	62	101	53	*E* 46[cc]	23	62	*W*39[c]	20	40	35	8	*E* 8[c]
10	56	66	28	50	19	52	21	20	41	*E* 59[bc]	15	19
11	*E* 65[c]	*E* 79[c]	17	56	*M*22[c]	52	15*	21	39[a]	53	8	21
12	70[bbd]	55	30	50	25	42[a]	*E* 26[c]	21[a]	33	48	15	17*
13	91[a]	47	26	60*	25*	37	16	23	39	56	0	15
14	89	37[a]	17	45[a]*	18*	23	24	13	23	38	12	22
15	96*	*E* 36[c]	*E* 28[c]	33*	32	21	25	10	28	32[a]	14[d]	22[a]
16	108*	22*	*M*44[c]	22*	41[d]	20	24[a]	9	17	24	21*	20
17	107	21*	52[b]	20*	35	16	29	10	8	11	26	30[d]
18	135[b]	23	44[a]	14	25	15	9	23[d]	0	22	31[d]	52[d]
19	95	17[a]	42*	10	31	9	8	23	7	22	43[b]*	*W*50[cc]
20	63	8	33	26	39	14	9	29	7	11	57	42
21	74[d]	10	31	30	31	8	25	31	8	8	63[dd]	33[c]
22	59	13	33[d]*	31[d]	33[b]	8	14	28	*M*10[c]	11[d]*	66	27
23	63	17[d]	8	28	45[d]	7	22	38	12*	18	68	29[a]
24	49[a]	20	24	23	67	10	14[a]	37[a]	18[d]	16	48[a]	42
25	39	16	17	*E* 24[c]	46	16	15	41	20	*M*29[c]	*W*58[c]	52[a]
26	34	15*	25[d]	25	*M*43[c]	14	16	*E* 35[c]	35[d]	37*	*E* 76[abc]	54
27	*E* 31[ac]	19	36	22	56	*E* 32[c]	18	37	33	*E* 63[c]	*E* 72[c]	33
28	46*	26[d]	31[a]	*E* 39[ac]	38[d]	28	34	43	31	53[b]*	67	19
29	60		30	34[a]	52[a]	29	33	53	27	49[b]*	61	8
30	67[d]*		*M*52[c]	46	48	31	10	50[a]	20[a]	49	51[a]	15
31	62		52		35		22[a]	47[a]		47		15
Mean	65.3	49.2	35.0	38.2	36.8	28.8	21.9	24.9	32.1	34.4	35.6	25.8

[a] Passage of an average sized group through the central meridian.

Figure 1 gives a graphical representation of the daily relative sunspot-numbers for 1930, the time being plotted as abscissas and the relative numbers as ordinates. The limits of the successive solar rotations are indicated by vertical arrows in the upper edge of the Figure. The secondary maxima and minima succeeding the rotation-periods do not represent real fluctuations in sunspot-activity, but are rather to be attributed to the influence of solar rotation, to a certain stability of the centres of activity for spots, and to the special distribution of these centres of activity in the direction of rotation.

Figure 2 shows the observed and smoothed monthly relative numbers for 1923 to 1930 (1923 year of the last sunspot-minimum). The purpose of smoothing is to eliminate the secondary variations. The method of smoothing is as follows: For obtaining the mean of the epoch July 1, the average of the monthly means of the twelve months January to December is taken (m_1), and for the epoch August 1. the average of the monthly means for February to January (m_2). The mean of these $m=(m_1+m_2)/2$, which represents the smoothed relative number for the middle of July, is used for the construction of the curve.

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REVIEWS AND ABSTRACTS

(See also pages 250 and 262)

VENSKE, O.: *Die erdmagnetischen Beobachtungen von Dr. Filchner auf seiner Reise in China und Tibet in den Jahren 1926-1928.* Berlin, Veröffentlichungen d. Preuss. Meteorol. Inst. Nr. 379 (Abhandlungen Bd. 9, Nr. 7), 1931 (28). 33 cm.

Very little was known about the Earth's magnetic field in Tibet before W. Filchner devoted his expedition of 1926-28 mainly to measurements of declination, horizontal intensity, and inclination. The length of his two routes is 6,000 kilometers. The northern route connected Tashkent (41°.3 N, 69°.3 E) with Tihua (43°.8 N, 87°.8 E) and Northwest-Kansu; the southern route crossed magnetic terra incognita, from Lussar (36°.5 N, 101°.7 E) over the Tangla Pass (32°.7 N, 92°.4 E; 5,010 m above sea-level) to Leh (34°.2 N, 77°.6 E). Observations were taken at about 150 stations, about 50 kilometers apart, with a magnetic theodolite, which was also equipped with soft iron induction-bars for measuring inclination. Hostility and distrust of the Tibetans, as well as privations, and at last ill-health of Filchner made the measurements trying, especially on the southern route.

These valuable observations were reduced by O. Venske. He estimates the mean errors in declination 6′, in horizontal intensity as low as 15γ, in inclination not more than 4′. The results are given in full. The declination-values vary little about 0°, confirming that the agonic runs east-west in Tibet. Local disturbances are small and less than in China; Venske concludes that the non-magnetic surface-rocks reach to great depths, which agrees with the results of observations of gravity.

J. BARTELS

MONTHLY MEANS OF AREAS OF THE OBSERVED PROMINENCES ON THE SUN'S LIMB FOR THE YEARS 1911–1930

By W. Brunner

The following table contains the monthly means of the measured areas of the observed prominences on the Sun's limbs. The unit area corresponds to a length of one degree in the direction of the Sun's limb and to a height of one second perpendicular to the limb. The numbers are based on observations made at the Zurich Observatory. The small numbers indicate the numbers of the monthly observations.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Mean
1911[1]	192_{29}	243_{25}	189_{27}	220_{31}	157_{28}	199_{29}	192_{32}	204_{31}	145_{25}	167_{31}	141_{24}	139_{14}	182_{326}
1912	104_{6}	45_{13}	102_{14}	136_{12}	101_{10}	97_{11}	101_{12}	240_{7}	103_{7}	198_{9}	217_{10}	73_{9}	126_{120}
1913	58_{5}	132_{16}	153_{16}	105_{10}	127_{15}	68_{8}	169_{10}	198_{7}	176_{5}	95_{12}	79_{5}	104_{5}	122_{114}
1914	73_{5}	261_{7}	128_{4}	212_{15}	290_{8}	377_{16}	326_{13}	559_{18}	286_{11}	687_{13}	417_{3}	533_{8}	346_{121}
1915	584_{2}	395_{5}	751_{7}	751_{14}	705_{7}	664_{10}	898_{12}	1040_{8}	943_{11}	802_{3}	820_{6}	1074_{2}	785_{87}
1916	498_{6}	1127_{8}	827_{4}	1087_{14}	1004_{11}	711_{7}	557_{13}	751_{10}	758_{7}	909_{11}	880_{5}	847_{4}	830_{100}
1917	1225_{3}	1134_{11}	618_{5}	785_{6}	842_{14}	1374_{20}	1790_{13}	1688_{11}	1627_{13}	1247_{8}	822_{6}	1097_{3}	1187_{113}
1918	930_{7}	763_{7}	1173_{16}	716_{6}	926_{18}	1567_{14}	1248_{14}	1010_{11}	660_{6}	978_{9}	595_{8}	554_{3}	927_{119}
1919	735_{3}	586_{9}	741_{8}	808_{6}	1172_{19}	1105_{15}	695_{13}	751_{16}	272_{12}	369_{8}	307_{7}	436_{1}	665_{117}
1920	816_{7}	640_{14}	583_{12}	1087_{6}	775_{21}	622_{15}	659_{18}	589_{14}	1123_{4}	923_{11}	725_{8}	$—_{0}$	777_{130}
1921	795_{8}	858_{15}	701_{22}	518_{9}	586_{16}	565_{12}	600_{24}	460_{16}	586_{11}	599_{17}	355_{8}	296_{3}	577_{161}
1922	177_{3}	277_{4}	378_{11}	466_{11}	501_{22}	427_{16}	648_{14}	351_{14}	573_{7}	394_{6}	560_{11}	637_{6}	449_{125}
1923[2]	370_{8}	283_{11}	342_{14}	481_{16}	432_{22}	392_{18}	386_{24}	351_{29}	302_{20}	385_{16}	395_{15}	485_{4}	384_{197}
1924	372_{6}	312_{6}	393_{16}	598_{9}	407_{13}	492_{11}	518_{17}	506_{7}	390_{11}	840_{18}	781_{11}	522_{15}	511_{140}
1925	575_{14}	456_{13}	413_{10}	702_{10}	548_{15}	727_{21}	718_{14}	665_{18}	878_{11}	783_{7}	$—_{0}$	755_{4}	657_{137}
1926	1323_{5}	1525_{9}	1532_{8}	1433_{10}	1342_{9}	1172_{13}	1229_{15}	1392_{31}	1198_{32}	1207_{14}	881_{10}	1185_{3}	1285_{162}
1927	1052_{5}	1050_{15}	1009_{11}	868_{14}	988_{27}	889_{23}	1014_{21}	765_{24}	858_{14}	649_{23}	720_{7}	742_{4}	884_{192}
1928	576_{7}	811_{16}	680_{16}	687_{13}	686_{14}	878_{18}	951_{28}	957_{18}	1123_{18}	798_{15}	975_{8}	911_{4}	836_{175}
1929	1056_{8}	806_{15}	942_{19}	828_{15}	712_{18}	754_{18}	916_{24}	858_{24}	936_{30}	1030_{13}	954_{13}	624_{7}	868_{204}
1930	748_{11}	748_{12}	467_{13}	770_{17}	640_{10}	420_{28}	363_{19}	316_{26}	266_{13}	268_{10}	232_{12}	414_{9}	471_{180}

[1] Zurich, Catania, Kalocsa, Madrid, Odessa, and Zo-Sé.
[2] Zurich and Dr. Scholl at Tölz.

THE MAGNETIC CHARACTER OF THE YEAR 1930[1]

By G. Van Dijk

The annual review of the "Caractère magnétique de chaque jour" for 1930 has been drawn up in the same manner as for the preceding years. Forty-six observatories contributed to the quarterly reviews; all of them sent complete data.

Table II of the annual review, containing the mean character of each day and each month, the lists of calm days and disturbed days, and the days recommended for reproduction are reprinted here.

Dates	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mean
1930																																
January	0.7	0.3	1.3	1.5	1.6	1.6	1.3	0.9	0.4	0.3	0.0	0.1	0.7	0.3	0.7	0.3	1.0	0.6	0.8	1.1	0.9	0.7	0.5	0.4	0.3	0.0	0.0	0.3	0.8	1.1	0.7	0.69
February	1.1	1.0	1.2	0.6	0.5	0.2	0.4	0.3	0.1	0.1	0.3	1.7	1.9	1.7	1.6	1.5	1.0	1.1	0.9	0.8	0.4	0.3	0.8	1.0	1.3	0.9	0.7	1.3				0.89
March	1.4	1.4	0.9	0.5	0.0	0.1	0.0	0.0	0.0	0.0	1.1	1.9	1.7	1.6	1.4	1.2	1.1	1.2	1.1	0.8	0.8	1.1	0.7	1.4	0.7	0.9	1.1	1.2	1.1	0.6	0.5	0.90
April	0.8	0.6	0.5	0.2	0.3	1.3	1.6	1.7	1.3	1.5	1.4	1.3	1.2	0.9	1.0	1.0	0.8	0.6	1.3	1.7	1.4	1.5	1.3	1.1	0.8	0.8	0.5	0.6	1.1	1.2		1.04
May	0.5	0.1	0.4	1.1	1.8	1.5	1.5	1.1	1.2	0.8	0.5	1.1	1.1	0.4	0.7	1.6	1.7	1.2	1.1	1.0	1.0	1.1	0.6	0.3	0.8	0.6	0.2	0.3	0.4	1.2	1.7	0.93
June	1.4	1.4	1.3	1.2	0.5	0.6	1.4	1.0	0.8	0.3	0.2	1.5	1.3	0.7	0.3	1.9	1.2	1.1	0.8	0.7	0.8	0.3	0.1	0.1	0.1	0.5	1.1	1.3	1.2	0.9		0.87
July	0.6	0.9	1.0	1.2	1.1	0.5	0.5	0.2	1.2	1.7	1.6	1.5	1.4	0.7	0.8	1.2	1.0	0.5	0.5	0.2	0.3	0.2	0.3	1.0	1.6	1.3	0.7	0.7	1.0	0.9	0.6	0.87
August	0.5	0.4	0.3	0.2	0.9	1.7	1.7	1.7	1.5	1.2	1.2	1.3	1.1	1.2	1.1	0.7	0.4	0.5	1.0	0.5	1.1	1.2	1.1	1.0	0.6	0.6	0.6	0.3	0.4	0.6	0.7	0.88
September	1.3	1.0	1.6	1.1	1.1	1.4	0.8	0.6	1.1	0.6	0.6	0.5	0.3	0.3	0.2	0.2	0.6	2.0	1.3	0.4	1.1	0.4	0.7	0.8	0.4	0.1	0.1	1.1	1.7	1.8		0.85
October	1.1	0.9	1.5	1.2	1.0	0.9	0.7	0.9	0.6	0.4	0.2	0.2	0.0	1.5	0.3	0.2	1.7	0.9	0.9	1.2	0.7	0.4	0.2	0.1	1.2	1.7	1.6	1.2	1.3	1.3	1.1	0.88
November	0.7	0.8	0.4	1.2	0.5	0.2	0.3	0.7	0.7	0.3	0.1	0.0	0.5	1.5	1.1	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.8	1.6	1.8	1.2	1.0	0.5	0.6	0.4		0.61
December	0.3	0.2	1.9	1.5	0.3	0.2	0.5	0.0	0.2	0.1	0.1	0.8	1.1	0.7	0.3	0.0	0.0	0.0	0.8	1.5	1.4	1.0	0.9	0.7	0.6	0.5	0.5	0.0	0.6	0.1	0.0	0.54

Month	Calm Days						Most Disturbed Days				
January	(0.08)	**11**,	**12**,	**14**,	**26**,	**27**	**3** (1.3),	**4** (1.5),	**5** (1.6),	**6** (1.6),	**7** (1.3)
February	(0.21)	**6**,	**8**,	**9**,	**10**,	**22**	**12** (1.7),	**13** (1.9),	**14** (1.7),	**15** (1.6),	**16** (1.5)
March	(0.04)	**5**,	**7**,	**8**,	**9**,	**10**	**1** (1.4),	**2** (1.4),	**12** (1.9),	**13** (1.7),	**14** (1.6)
April	(0.41)	**3**,	**4**,	**5**,	**27**,	**28**	**7** (1.6),	**8** (1.7),	**10** (1.5),	**20** (1.7),	**22** (1.5)
May	(0.27)	**2**,	**3**,	**24**,	**27**,	**28**	**5** (1.8),	**6** (1.5),	**16** (1.6),	**17** (1.7),	**31** (1.7)
June	(0.15)	**11**,	**15**,	**23**,	**24**,	**25**	**1** (1.4),	**2** (1.4),	**7** (1.4),	**12** (1.5),	**16** (1.9)
July	(0.24)	**8**,	**20**,	**21**,	**22**,	**23**	**10** (1.7),	**11** (1.6),	**12** (1.5),	**13** (1.4),	**25** (1.6)
August	(0.32)	**2**,	**3**,	**4**,	**17**,	**28**	**6** (1.7),	**7** (1.7),	**8** (1.7),	**9** (1.5),	**12** (1.3)
September	(0.20)	**14**,	**15**,	**16**,	**26**,	**27**	**3** (1.6),	**6** (1.4),	**18** (2.0),	**29** (1.7),	**30** (1.8)
October	(0.13)	**11**,	**13**,	**16**,	**23**,	**24**	**3** (1.5),	**14** (1.5),	**17** (1.7),	**26** (1.7),	**27** (1.6)
November	(0.01)	**12**,	**19**,	**20**,	**21**,	**22**	**4** (1.2),	**14** (1.5),	**24** (1.6),	**25** (1.8),	**26** (1.2)
December	(0.01)	**8**,	**16**,	**17**,	**18**,	**31**	**3** (1.9),	**4** (1.5),	**13** (1.1),	**20** (1.5),	**21** (1.4)

Days Recommended for Reproduction

** June 16, September 18, December 3; * February 13, March 12, May 5, May 31, July 9, October 17, November 25.

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[1] Terr. Mag. **33**, 203 (1928); **34**, 207 (1929); **35**, 178 (1930).

TWENTY-FIFTH ANNIVERSARY OF THE FOUNDATION OF THE OBSERVATORIO DEL EBRO

In view of the important place in astronomical and geophysical investigation occupied by the Observatorio del Ebro and of the valuable contributions made from time to time by its distinguished director, Father Luis Rodés, to the pages of this JOURNAL, it seems fitting that we should take this occasion of its twenty-fifth anniversary to record our appreciation and admiration of the fine work accomplished. Although the private inauguration of the Observatory took place September 8, 1904, its official existence is reckoned from the day of the total solar eclipse of August 30, 1905, since, as the Director facetiously remarked in his anniversary discourse, it is better for a scientific institution to begin with a total eclipse than to end with one. The celebration of the twenty-fifth anniversary, however, was for various reasons postponed until October 26, 1931, but chiefly because of the desire to inaugurate at the same time the "Lánderer Pavilion," which is to serve as a library and astrophysical museum. This building was erected in honor of the prominent scientist, José Joaquín Lánderer, who collaborated zealously in the foundation of the Observatory and at his death bequeathed to it his property.

Invitations to the celebration were issued to the principal scientific centers of Spain and to special friends and supporters of the Observatory. In general, invitations were not sent to institutions outside of Spain, but exceptions were made in the cases of the Astronomical Society of France and the Academy of Sciences of Portugal, both of which were represented at the festivities. The program, which began at Tortosa, included visits to the Cathedral and park at Tortosa, banquet offered by the Observatory, benediction and inauguration of the Lánderer Pavilion by Dr. Félix Bilboa, Bishop of the Diocese, followed by a few words of the founder, Father Ricardo Cirera, and an address by the present director, Father Luis Rodés. The various buildings were then visited.

The Observatorio del Ebro is an institution of private character belonging to the Company of Jesus. It was, however, early recognized by the Government of Spain as an institution of public utility, and has accordingly felt obliged, as far as feasible, to render various services to the State. It is situated at Roquetas, about 2.5 km from the center of the city of Tortosa, in latitude 40° 49′ north, longitude 0° 31′ east of Greenwich, hence, in the extreme south of Catalonia, in a picturesque region abounding in olive and fruit trees, forming an excellent setting for an observatory of this kind. The purpose had in view by its founder was to collect data necessary for the investigation of the relations between solar activity and the various phenomena observed on our planet, particularly those of electricity and magnetism, for which reason no less

than 30 different phenonema are recorded continuously and simultaneously at the Observatory. It is therefore a cosmical-physics observatory in which it is sought to discover possible relationships between extra-terrestrial phenomena, especially those of the Sun, and those which occur on the Earth. At the same time it is an astrophysical and geophysical observatory.

The Observatory is divided into three principal sections: (1) *Geophysical*, which concerns itself with earthquakes, terrestrial magnetism, and earth-currents; (2) *electro-meteorological*, in which observations of solar radiation, movements of the atmosphere, meteorological elements, and atmospheric electricity are made; (3) *heliophysical*, in which are observed phenomena on the Sun's surface, such as spots, faculae, clouds, prominences, etc. Thus under these three sections are grouped activities which are often distributed among several organizations. This concentration of activities under one general direction makes possible the publication in a monthly bulletin of the results of the observations in these various branches, thereby facilitating comparative study by those desiring to utilize them.

In addition to the services of observation and registration above mentioned, the Observatory maintains a large reference-library containing the fundamental works on geophysics and astronomy. The number of books and pamphlets received each year approximates 1,000, and about 300 periodical publications are kept on file.

The extensive activity of the Observatory is reflected in its technical publications, consisting of six memoirs, describing the work of the different sections and certain special investigations, and the *Monthly Bulletin*, which began in 1910 and brings each month the numerical values of the elements recorded under the three principal captions, heliophysics, electro-meteorology, and geophysics. At the end of each bulletin are given synoptic curves presenting visually the numerical values contained in the preceding tables. Of more popular nature is a large body of writings, among which may be mentioned the well-known volume "El Firmamento," by Father Rodés, and numerous articles contributed to reviews and journals.

The theoretical interpretation of the results obtained has also received attention. Thus, for example, an ingenious theory regarding the cause and propagation of magnetic storms was elaborated and published in this JOURNAL by Father Rodés. This theory, which gave rise to considerable discussion, was based on the assumption that magnetic disturbances owed their inception and progressive movement to clouds of electric particles ejected from zones of solar activity, through which the Earth advanced much as through the shadow of the moon, the striking of the electric cloud provoking a perturbation in the Earth's magnetic field.

Of more practical nature, however, is the important service rendered in the preparation of the recent magnetic map of Spain. Not only did the Observatory serve as the base-station, but also took upon itself a large part of the tedious computational work incident to this enterprise.

The value of the work done in connection with earth-currents can hardly be overestimated from a theoretical viewpoint. The Observatorio del Ebro is one of the very few observatories where earth-currents are regularly recorded and has to its credit the longest series of such

records in existence. With the aid of these, investigations of relationships with other cosmical and geophysical phenomena over a considerable period of years were first possible, and these studies have led to the confirmation of certain hypotheses, heretofore only assumed, and the deduction of new and important conclusions.

Thus the ambitious vision of the founder and first director, Father Ricardo Cirera, who spent four years in travel and study and in maturing plans for this Observatory, has, during the first five lustra of its existence, become a reality, and, knowing the high scientific qualifications and enthusiasm of the present director and his staff, we have every reason to look forward to even greater achievements in the future.

DEPARTMENT OF TERRESTRIAL MAGNETISM, H. D. HARRADON
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AMERICAN *URSI* BROADCASTS OF COSMIC DATA[1]

Summary American URSI daily broadcasts of cosmic data, May to July, 1931

Day	May							June							July						
	Magnetism			Sun-spot		Solar constant		Magnetism			Sun-spot		Solar constant		Magnetism			Sun-spot		Solar constant	
	Char.	Type	G. M. T. begin. distur.	Groups	No.	Value	Char.	Char.	Type	G. M. T. begin. distur.	Groups	No.	Value	Char.	Char.	Type	G. M. T. begin. distur.	Groups	No.	Value	Char.
			h m							*h m*							*h m*				
1	0	..	.. ....	1	2	1.924	*f*	0	..	15 30	1	6	1.946	*f*	0		.. ...	...	...	......	..
2	0	..	.. ....	1	1	1.937	*s*	2	*i*	.. ....	2	9	......	..	0	..	.. ...		19	......	..
3	0	..	.. ....	1	1	......	..	1	*i*	.. ....	3	20	1.941	*f*	0	.	.. ...	2	15	......	..
4	0	..	.. ....	1	2	1.936	*s*	1	*i*	.. ....	2	21	1.946	*f*	0	.	.. ...	3	11	......	..
5	0	..	.. ....	2	4	1.939	*s*	0	..	.. ....	...	....	1.943	*f*	0	.	.. ...	3	12	......	..
6	1	*i*	.. ....	2	4	1.935	*s*	0	..	.. ....	...	....	1.946	*f*	0	..	.. ...	3	12	1.953	*f*
7	1	*p*	2	2	3	1.941	*s*	0	..	.. ....	...	....	1.942	*s*	0	..	.. ...	5	12	1.951	*u*
8	1	*p*	.. ....	2	3	1.934	*s*	0	..	.. ....	...	....	1.924	*u*	0	..	.. ...	4	9	1.954	*s*
9	0	..	.. ....	2	14	......	..	1	*i*	.. ....	2	12	1.941	*f*	0	..	.. ...	3	10	1.957	*s*
10	0	..	.. ....	2	18	1.942	*f*	1	*o*	6 00	3	15	1.939	*f*	0	..	.. ...	4	11	1.951	*s*
11	0	..	.. ....	2	20	1.935	*f*	0	..	.. ....	2	11	......	..	0	..	.. ...	4	11	1.954	*f*
12	1	*o*	.. ....	3	13	1.952	*s*	0	..	.. ....	2	6	1.946	*f*	0	..	.. ...	4	9	1.945	*s*
13	0	..	.. ....	3	12	1.926	*u*	0	..	.. ....	...	....	......	..	0	..	.. ...	4	5	1.921	*u*
14	1	*i*	16	1	21	1.953	*f*	0	..	.. ....	1	4	......	..	0	..	.. ...	3	5	......	..
15	2	*i*	.. ....	4	31	1.942	*f*	1	*b*	4 15	...	....	......	..	0	..	.. ...	...	...	......	..
16	1	*i*	.. ....	3	28	......	..	0	..	.. ....	...	....	1.960	*f*	1	*b*	2 ...	1	1	......	..
17	0	..	.. ....	3	12	......	..	0	..	.. ....	...	....	1.942	*f*	0	.	.. ...	1	3	1.952	*f*
18	0	..	.. ....	3	10	......	..	0	..	.. ....	1	1	1.950	*f*	1	*b*	7 ...	2	3	1.951	*f*
19	0	..	.. ....	2	7	1.958	*f*	0	..	.. ....	...	....	1.955	*u*	0	..	.. ...	0	0	1.946	*f*
20	0	..	.. ....	1	13	1.951	*f*	0	..	.. ....	...	....	1.942	*f*	0	..	.. ...	1	1	1.947	*f*
21	0	..	.. ....	2	15	1.952	*f*	0	..	.. ....	...	....	1.943	*s*	0	..	.. ...	1	4	1.944	*f*
22	0	..	.. ....	...	....	1.958	*f*	1	*i*	.. ....	...	....	......	..	0	..	.. ...	...	...	1.950	*f*
23	0	..	.. ....	3	11	1.946	*f*	0	..	.. ....	...	....	......	..	1	*i*	3 20	1	2	1.947	*f*
24	0	..	.. ....	...	....	1.950	*f*	0	..	.. ....	...	....	1.941	*f*	2	*i*	.. ...	1	2	1.933	*u*
25	0	..	.. ....	...	....	1.944	*f*	0	..	.. ....	...	....	1.946	*f*	1	*i*	.. ...	1	2	......	..
26	1	*p*	.. ....	3	8	1.938	*f*	0	..	15 00.0	...	....	1.943	*f*	2	*i*	.. ...	1	1	1.942	*f*
27	0	..	.. ....	3	15	1.942	*f*	2	*i*	.. ....	1	4	1.948	*s*	0	..	.. ...	...	...	1.941	*f*
28	0	..	.. ....	2	12	......	..	2	*i*	.. ....	1	4	1.946	*f*	1	*i*	3 ...	1	3	......	..
29	0	..	.. ....	2	9	1.942	*f*	1	*i*	.. ....	3	6	1.954	*f*	1	*p*	... ...	...	...	......	..
30	0	..	.. ....	2	5	1.941	*u*	1	*i*	.. ....	4	11	1.935	*u*	1	*i*	.. ...	2	8	1.938	*u*
31	0	..	.. ....	2	6	1.948	*f*								0	..	.. ...	2	10	1.934	*f*
Mean	0.3	..	.. ....	2.4	10.7	1.943	..	0.5	..	.. ....	2.0	9.3	1.944	..	0.4	..	.. ...	2.3	7.0	1.946	..

Greenwich mean time for endings of storms: $7^h 30^m$, May 6; 6^h, May 12; 10^h, May 15; $1^h 30^m$, June 4; $10^h 00^m$, June 10; 10^h, June 30; 3^h, July 16; 8^h, July 18; 3^h, July 24; 7^h, July 29.

[1] For previous announcements see Terr. Mag., **35**, 184-185 and 252-253 (1930); **36**, 54 and 141 (1931).

The first three columns of the Table give (1) the magnetic character according to the scale 0-2 of the International Commission of Terrestrial Magnetism and Electricity, (2) the type featuring the day other than normal by the letters *b*, *p*, *o*, and *i* for days marked by bay, rapid pulsations, long-period oscillations, and irregular oscillations, respectively, and (3) the hour and minute of Greenwich mean time marking the beginning of a storm, the end of the storm being indicated in the footnote to the Table. The next two columns give the data relating to sunspots: (1) the number of groups of spots and (2) the total number of spots. It is to be noted that sunspot-numbers such as those from Zürich can be obtained from the number of groups and spots given in the Table by the formula $N=k\ (10g+s)$, where k for Mount Wilson is about 0.77. The sixth and seventh columns show (1) the value in calories of the solar constant, and (2) by letters *s*, *f*, and *u*, whether the determination was satisfactory, fair, or unsatisfactory, respectively.

Beginning June 1, 1931, the American URSI broadcasts of cosmic data are including, under the identifying mark, KHL, coded information concerning Kennelly-Heaviside layer heights. These are furnished by the United States Bureau of Standards, Washington, D. C. The broadcast information gives place of observation, frequency in kilocycles per second, day of week, nearest hour in G. M. T., and height of the layer in kilometers. A decoded tabular summary of the KHL data for June and July, 1931, is presented here.

Kennelly-Heaviside Layer Heights, Washington, D. C.

Date	Frequency	Nearest hour, G.M.T.	Height	Date	Frequency	Nearest hour, G.M.T.	Height
1931	*kc/sec*	*h*	*km*	*1931*	*kc/sec*	*h*	*km*
June 1	5,000	22	330, 420, 660	July 10	5,000	4	330
" 2	5,000	4	390, 820	" "	3,000	16	No value obtained
" 12	2,000	16	No value obtained	" "	4,100	16	100
" "	5,000	17	110, 230	" "	5,000	16	No value obtained
" 19	2,000	20	No value obtained	" 17	3,000	17	110
" "	4,100	20	290	" "	4,100	17	210
" "	5,000	20	340, 430, 830	" "	4,100	16	300
" 20	4,100	5	330	" "	5,000	17	660
" "	5,000	5	No value obtained	" 23	3,000	5	100
" 26	2,000	5	320	" "	3,000	7	110
" "	4,100	5	340, 480, 730	" "	6,800	5	100
" "	5,000	5	No value obtained	" "	7,000	5	130
" "	2,000	16	No value obtained	" "	7,700	5	No value obtained
" "	3,000	16	110	" "	5,000	7	110
" "	4,100	16	230	" "	5,500	8	No value obtained
" "	5,000	16	130, 350	" 24	3,000	16	100
" "	6,000	16	130	" "	6,000	16	100
" "	7,000	16	130	" "	7,600	16	130
July 7	4,100	20	120, 280	" "	8,650	16	140
" "	5,000	20	130, 370	" "	9,000	16	60

Effective July 1, 1931, the following changes in code were made: RAD now designates solar constant previously designated SOL. SOL now designates sunspots previously designated SUN. This change was made in order to have the SOL designation conform with the French code-word for sunspots.

Department of Terrestrial Magnetism,
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Washington, D. C.

Katharine B. Clarke

PROVISIONAL SUNSPOT-NUMBERS FOR MAY, JUNE, AND JULY, 1931

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	May	June	July	Day	May	June	July
1	17	13	22	17	29	0	8
2	8	*E* 28[c]	23	18	. .	7	7
3	7	34	23	19	34	0	0
4	8	36	19	20	. .[b]	0	0
5	8	30[a]	19[a]	21	*E* 30[c]	0	*E* 7[c]
6	17	36	16	22	26	7	10
7	17[d]	32	*E* . .[c]	23	35	0	8
8	26	*M*44[c]	35	24	32	0	8
9	*M*20[c]	35	28	25	31	0	8
10	33	47	M48[ac]	26	*W*35[c]	0	0
11	33	20	35	27	35	*E* 8[c]	*E* 7[c]
12	26	14	26	28	20	10	9
13	32[a]	0	30	29	19	25[d]	*E* 22[c]
14	17	*W*10[c]	23	30	20[d]	23	23
15	*E* 36[c]	0	8	31	11 (?)	. .	23
16	37	0	7				
				Means	24.1	15.3	16.7
				No. days	29	30	30

Mean for quarter April to June, 1931: 23.4 (88 *days*).

[a]Passage of an average-sized group through the central meridian.

[b]Passage of a larger group through the central meridian.

[c]New formation of a large or average-sized center of activity; *E*, on the eastern part of the Sun's disc; *W*, on the western part; *M*, in the central zone.

[d]Entrance of a large or average-sized center of activity on the east limb.

Zürich, Switzerland W. BRUNNER

PROVISIONAL SOLAR AND MAGNETIC CHARACTER-FIGURES, MOUNT WILSON OBSERVATORY, APRIL, MAY, AND JUNE, 1931[1]

Two magnetic storms in which the range in the horizontal intensity exceeded 100γ were recorded in the second quarter of 1931. There was no special solar activity to which either of these storms could be attributed.

Greenwich mean time			Range
Beginning		Ending	Hor. int.
1931	*h m*	*d h m*	γ
May 7	1 . .	8 07 . .	102
June 26	15 00	29 00 . .	131

On June 15, at 4^h 14^m, G. M. T , the horizontal intensity changed rapidly, making a record similar to that of a "sudden commencement," but in this case no storm followed.

[1] For previous tabulations from November 1929, see Terr. Mag., **35**, 47-49, 92, and 249-251 (1930), and **36**, 55-56, and 142-143 (1931).

April, 1931

Day	K_2 A	K_2 B	$H\alpha B$ A	$H\alpha B$ B	$H\alpha D$ A	$H\alpha D$ B	No. groups	Mag'c char.
1	2	2	2	2	1	1	5	0
2	2	2	2	2	2	3	6	0.5
3	2	2	2	2	2	3	5	0.5
4	1	1	1	1	1	1	5	0
5	....	....	....	....	....	....	......	0
6	....	....	....	....	....	....	4	0
7	1.5	1	2	1	1	0	3[b]	0
8	1.5	2	2	2	2	1	3	0
9	1.5[a]	2[a]	2	2	1	0	3[b]	0.5
10	1.5	2	2	2	1	0	3	1.0
11	....	....	....	....	....	....	4	0.5
12	1.5	1	1.5	1	1	1	5	0
13	2	1	2	1	1	0	5	0
14	2	1	2	1	2	1	4	0
15	2	2	2	3	2	2	3	0
16	2	3	2	3	2	2	6	0
17	2	2	3	3	1	1	6	0
18	2	2	3	2	1	1	3	1.0
19	2	1	2	1	2	0	2	1.0
20	1	1	2	1	2	0	3	......
21	1	1	2	1	2	0	3	0.5
22	....	....	....	....	....	....	3	0.5
23	....	....	....	....	....	....	......	0
24	....	....	....	....	....	....	......	0
25	....	....	....	....	....	....	......	0
26	....	....	....	....	....	....	......	0.5
27	....	....	....	....	....	....	......	0
28	1	1	1	1	1	0	2	0
29	1	1	1	1	2	1	2	0
30	1	1	1	1	2	1	2	0
31								
Mean	1.6	1.5	1.9	1.6	1.5	0.9	3.8	0.2

May, 1931

Day	K_2 A	K_2 B	$H\alpha B$ A	$H\alpha B$ B	$H\alpha D$ A	$H\alpha D$ B	No. groups	Mag'c char.
1	1	1	1	1	1	1	1	0
2	1	1	1	1	2	0	1	0.5
3	1	1	1	1	2	1	1	0
4	1	1	1	1	2	3	1	0
5	0.5	1	1	1	2	3	2	0
6	0.5	1	1	1	2	3	2	1.0
7	1	1	1	1	2	2	2	1.5
8	1	1	1	1	3	2	4	0.5
9	1	1	1	1	2	1	3	0
10	1	1	2	1	2	2	3	0
11	1	2	2	2	2	2	3	0.5
12	2	3	2	3	2	3	4	0.5
13	2	3	2	3	2	2	4[b]	0.5
14	1	2	2	2	1	1	3	0.5
15	1	1	1	1	1	0	5	1.0
16	1	0	1	0	1	0	4	0.5
17	1	0	1	0	1	0	4	0
18	1	1	1	1	2	0	4	0
19	1	1	1[c]	2[c]	2	1	3	0.5
20	1[d]	2[d]	2[c]	2[c]	1	1	2[b]	0
21	1	2	2	2	2	2	2	0
22	1	1	2	1	2	3	3	0
23	1	1	1	1	2	0	3	0
24	....	....	....	....	....	....	......	0
25	....	....	....	....	....	....	......	0
26	1	1	1	1	1.5	0	3	0.5
27	1	1	1	1	1.5	1	3	0.5
28	1	0	1	0	1	0	2	0
29	1	0	1	0	1	0	2	0
30	1	0	1	0	1	1	2	0
31	1	0	1	0	1	0	2	0
Mean	1.1	1.1	1.3	1.1	1.7	1.2	2.7	0.3

June, 1931

Day	K_2 A	K_2 B	$H\alpha B$ A	$H\alpha B$ B	$H\alpha D$ A	$H\alpha D$ B	No. groups	Mag'c char.
1	1	1	1	0	1	2	3	0.5
2	1	1	1	1	1	1	3	1.0
3	1	2	1	1	1	1	4	0.5
4	2	2	2	2	1	2	2[b]	0
5	....	....	....	....	....	....	..[b]	0
6	....	....	....	....	....	....	2	0
7	....	....	....	....	....	....	......	0
8	....	....	....	....	....	....	......	0.5
9	2	3	2	3	1	1	3	1.0
10	2	3	1	2	2	1	4	0.5
11	2	2	1	1	1	1	2	0.5
12	1	0	1	0	2	1	2	0.5
13	1	0	1	0	1	1	0	0
14	1	1	1	0	1	1	1	0
15	1	1	1	1	1	1	0	0.5
16	....	....	1	1	1	0	0	0
17	1	1	1	1	1	1	1	0
18	1	1	1	1	1	1	1	0
19	1	1	1	1	1	1	0	0
20	1	1	0	0	1	0	0	0
21	1	1	1	1	2	1	0	0.5
22	1	1	1	1	1	0	0	0.5
23	1	1	1	0	1	0	0	0
24	1	0	1	0	2	0	0	0
25	1	0	0	0	1	1	0	0
26	1	0	0	0	1	2	1	1.0
27	1	1	1	0	1	1	1	1.0
28	1	1	0	0	1	2	2	1.0
29	1	1	0	0	1	1	3	0.5
30	1	2	1	1	1	1	2	0.5
31								
Mean	1.2	1.1	0.9	0.7	1.1	1.0	1.4	0.4

[a] Small areas very bright, K_2 developed in large north central group between $16^h\ 22^m$ and $16^h\ 31^m$ G. C. T. [b] Passage of an average-sized group through the central meridian within 15° of the center of the disk. [c] Very bright $H\alpha$ south central group. [d] Small area very bright K_2 south central group.

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SETH B. NICHOLSON
ELIZABETH E. STERNBERG

POSSIBLE CONNECTION BETWEEN LARGE TEMPORARY MAGNETIC DISTURBANCES AND EARTHQUAKES

Referring to my article in the June 1930 issue of the Journal, I have received a letter from Professor Tanakadate stating that the records of the Kakioka Magnetic Observatory show no unusual features on August 3, 4, 5, 1926.

Imperial College of Science and Technology, London, England S. Chapman

REVIEWS AND ABSTRACTS

(See also pages 250 and 253)

Fleming, J. A. (Editor): *Transactions of the American Geophysical Union; Twelfth annual meeting, April 30 and May 1, 1931.* Washington, D. C., National Research Council, June, 1931 (229 with illus.). 25 cm.

The American Geophysical Union, which is the American National Committee of the International Union of Geodesy and Geophysics, and the executive committee of which is the Committee on Geophysics of the American National Research Council, held its twelfth annual assembly on April 30 and May 1, 1931, in Washington, D. C. The *Transactions* before us contain the reports and papers presented at the general assembly and at the meetings of the seven sections which constitute the Union. At this meeting the Section of Hydrology, established on November 13, 1930, participated for the first time.

At the general assembly five resolutions emanating from various sections were read and adopted referring to (1) gravity at sea, (2) international coöperation in the study of tidal waves, (3) comparison of new types of seismological instruments developed in the United States, with various types developed in Europe, (4) fiftieth anniversary of General Greely's participation in the First International Polar Year 1882–1883, and (5) the death of Franklin G. Tingley, late chief of the Marine Division of the United States Weather Bureau.

In his report, the General Secretary gave a brief account of the Stockholm Assembly of the International Union of Geodesy and Geophysics and of the proposed geophysical work in the polar regions. With regard to the latter topic, he sketched the status of the proposed Jubilee International Polar Year, 1932–33, with special reference to American participation therein, presented a progress-report of the Wilkins-Ellsworth Trans-Arctic Submarine Expedition, and touched upon the projected trial arctic flight in July of the *Graf Zeppelin* under the auspices of Aeroarctic.

This report was followed by a "Symposium on time-signals," sponsored by the sections of Geodesy and Seismology, in which the great need of additional time-signals was emphasized. Not only are the papers reproduced in their entirety, but also the informal communications and the principal points brought out in the discussion, are included.

The various aspects of the Polar Year, which had received the unanimous endorsement of the Union at the previous meeting in 1930, gave rise to a number of papers and considerable discussion in the Sections of Meteorology and of Terrestrial Magnetism and Electricity, since these two sections are especially interested in the work planned. In the Section of Meteorology A. J. Henry introduced the subject by giving an account of the First International year 1882-83, and H. H. Kimball outlined the general character of the meteorological program of the forthcoming enterprise. C. F. Marvin and J. Patterson indicated the nature of the expected coöperation of the United States Weather Bureau and the Meteorological Service of Canada, respectively. At the meeting of the Section of Terrestrial Magnetism and Electricity, papers were also presented having direct reference to the Polar-Year program. W. J. Peters discussed the advantages and difficulties of making magnetic observations on a moving ice-floe and H. W. Fisk presented isomagnetic charts (declination, magnetic meridians, inclination, total intensity, and horizontal intensity) of the arctic area for the epoch 1925. Although these charts had to be based on relatively meager data, it is believed that they present a picture of the magnetic distribution which may serve as a basis upon which a more accurate series may be constructed as the essential facts become better known. O. H. Gish discussed the significance of geoelectrical data from the polar

regions, his purpose being to present reasons for considering observations of atmospheric electricity and earth-currents at a few polar stations. H. B. Maris outlined a program of work for a station at Fort Conger—the station occupied in 1882 by General A. W. Greely. In this program eleven projects are included: Radio communication, radio reflections, terrestrial magnetism, terrestrial electricity, geology, biology, atmospheric radiation, atmospheric absorption, aurora, meteorology, and upper-air observations.

The activity and progress in the domains represented by the seven sections of the Union are reflected in the many important reports and papers reproduced in the *Transactions*. Those presented at the Section of Terrestrial Magnetism and Electricity, the program of which was unusually comprehensive, naturally are more closely allied to the special province of this JOURNAL than those of the other sections. They were given in four groups relating to (1) the year's investigations in progress in the United States, (2) the Stockholm assembly, (3) extra-terrestrial considerations, and (4) polar research, to which reference has already been made. The first group included the following reports: Magnetic work of the United States Coast and Geodetic Survey, 1930–31, by D. L. Hazard; field- and laboratory-investigations of the Carnegie Institution of Washington, by J. A. Fleming; recent developments in radio-transmission measurements, by G. W. Kenrick and G. W. Pickard; the URSI cosmic data radio broadcast, by Watson Davis; reports of geomagnetic and electric work of organizations and individual investigators in the United States, 1930–31, by H. W. Fisk; reports submitted on work in terrestrial magnetism and atmospheric electricity. These last consisted of brief progress-reports submitted by 14 governmental and private organizations in the United States, and bear witness to the widespread interest and activity in these two sciences.

A general report on the work done at the Stockholm assembly of the Section of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics summarized the status of international geophysical activity as opposed to the national aspects presented in the preceding group of papers.

The third group relating to extra-terrestrial relations consisting of reports of investigational character, included: Investigations at the Perkins Observatory of changes in the Kennelly-Heaviside layer as a function of lunar altitudes, by H. T. Stetson; Notes on correlation-investigations between Kennelly-Heaviside layer and lunar altitudes, by G. W. Pickard; Use of magnetic data for investigating radiation from the Sun, by J. Bartels; The electrical state of the Sun, by Ross Gunn; The ultraviolet-light theory of comet-activity, by H. B. Maris.

As in the case of the previous issue, the present *Transactions* have been produced by the photo-offset process—permitting complete publication within two months after the meeting.

H. D. HARRADON

KNOCH, K.: *Klimakunde von Südamerika.* Handbuch der Klimatologie herausgegeben von W. Köppen und R. Geiger. Band II, Teil G, Berlin, Gebrüder Borntraeger, 1930 (viii+349) 26 cm. Preis *RM.* 67.50.

Not since the appearance of the third edition of Hann's "Handbuch der Klimatologie" in 1911 has there been an attempt to compile and present in concise and readily available form the vast amount of meteorological data collected from all parts of the world. Therefore the efforts of Köppen and Geiger, with the coöperation of leading climatologists from each continent, in editing the new series of climatological handbooks will be appreciated by climatologists and meteorologists as well as by geophysicists, travelers, and others who seek authentic and up-to-date information concerning the factors of weather which combine to make up the climate of a region and play an important rôle in many geophysical investigations.

Band II, Teil G, "Klimakunde von Südamerika" is one of the first numbers of this ambitious series to appear. The book is divided into six chapters. Chapters 1 and 2 include a discussion of the methods and meteorological factors, chapter 3 includes the climates of the countries of South America, chapter 4 classifies the climates according to the Köppen formula, chapter 5 gives tables of meteorological data, and chapter 6 supplies a comprehensive bibliography.

The immediate interest of this handbook to those concerned with atmospheric electricity is the discussion of thunder-storm data on pages 91 to 95. Figure 39 shows the distribution of frequency of thunder-storms drawn from the data, giving for each station the number of days during each month when a thunder-storm was recorded. In general, greatest frequencies are found within the tropics at the equinoxes and outside the tropics in the summer season, times when moisture- and heat-conditions are most conducive to strong vertical convection. This general distribution, however, is disturbed by local factors of elevation and promixity to water-bodies.

KATHARINE B. CLARKE

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Aeroarctic. Karte der magnetischen Meridiane für 1931 zwischen Nowaja Semlja und Neu-Sibirischen Inseln. Massstab 1:5,000,000. 118x108 cm. Entworfen von K. Haussmann. Herausgegeben von der Internationalen Gesellschaft Aeroartic, Berlin, in winkeltreuer Lambertscher Zylinderprojektion nach Catalogue of magmetic determinations in U. S. S. R. and in adjacent countries, by B. P. Weinberg, Leningrad, 1929, nach handschriftlichen Aufzeichnungen von Prof. Weinberg, und nach Curves of equal magnetic variation 1927, published at the Admiralty, London.

American Geophysical Union. Transactions of the American Geophysical Union. Twelfth annual meeting, April 30 and May 1, 1931. Edited by J. A. Fleming, General Secretary. Washington, D. C., Nation. Res. Council, June, 1931 (229 with illus.). 25 cm. [For abstract of these Transactions, see this issue of the Journal.]

Apia Observatory. Report for 1927. Published by the direction of the Honorary Board of Advice, Wellington, N. Z. Wellington, W. A. G. Skinner, Govt. Printer, 1929 (86). 25 cm.

Berlin, Preussisches Meteorologisches Institut. Bericht über die Tätigkeit des Preussischen Meteorlogischen Instituts im Jahre 1930. Mit einem Anhang, enthaltend wissenschaftliche Mitteilungen. Berlin, Veröff. met. Inst., Nr. 380, 1931 (195). 25 cm. [Contains reports on atmospheric electricity and terrestrial magnetism, pp. 35-49.]

Bittinger, C., and E. O. Hulburt. Zodiacal light and magnetic disturbance. Phys. Rev., Menasha, Wis., v. 37, No. 9, 1931 (1190). [During a trip from Norfolk, Virginia, to Cape Miasi, Cuba, zodiacal light was observed on the evenings of March 13 to 18, 1931. It was very bright on the first two evenings, growing fainter and assuming normal brightness on the 18th. On examining magnetic data from Cheltenham, Tucson, and Meudon observatories, it was found that a moderate disturbance prevailed during the period March 11 to 14, with magnetic calm from March 15 to 20.]

Coldewey, H. Zur Aenderung der Deviationsformel. Ann. Hydrogr., Berlin, Jahrg. 59, Heft 5, 1931 (184-185).

De Bilt, Meteorological and Magnetic Observatory. Annuaire. Quatre-vingt-et-unième année 1929. B. Magnétisme terrestre. (K. Nederlandsch Met. Inst. No. 98.) Amsterdam, 1930 (ix+24). 34 cm.

Dyson, F. W. Report of the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich. Read at the Annual Visitation of the Royal Observatory, 1931, June 6. Greenwich, Royal Observatory, May 31, 1931 (17). 31 cm. [The report refers to the period May 11, 1930, to May 10, 1931, and contains an account of the magnetic work at Abinger Observatory during that time.]

Fanselau, G. Ueber Messungen mit dem Doppelkompass. (Im Anhang, Bericht Preuss. met. Inst. 1930.) Berlin, Veröff. met. Inst., No. 380, 1931 (186-193).

Filippo, D. di. Le formule di Biot-Mollweide e di Pinto in confronto coi valori degli elementi magnetici della Somalia. Roma, Rend. Acc. Lincei, Ser. 6, v. 13, sem. 1, fasc. 3, 1931 (186-190).

Fleming, J. A. The magnetism of the Earth. Sci. Mon., New York, N. Y., v. 33, No. 1, 1931 (74-77).

Hongkong, Royal Observatory. Report of the Director of the Royal Observatory, Hongkong, for the year 1930. Hongkong, Noronha and Co., 1931 (19). 25 cm. [Contains tables giving annual values of the magnetic elements for 1930 as derived from 52 determinations, and magnetic character of the year 1930 at Hongkong.]

KOENIGSBERGER, J. Remanenter und induzierter Magnetismus bei Einlagerungen. Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 1, Heft 4, 1931 (469-471).

LEGRAND, H. Mission hydrographique de la Guyane. Ann. hydrogr., Paris, Sér. 3, T. 10 (1930), 1931 (195-204). [The magnetic declination was determined on September 17, 1929 on the *Îlet la Mère* near the landing-place. The value was found to be 10° 58′.7 W (1929.7).]

LOVÖ. Ergebnisse der Beobachtungen des magnetischen Observatoriums zu Lovö (Stockholm) im Jahre 1929. Stockholm, Kung. Sjökarteverket, 1931 (29). 31 cm.

MARIS, H. B. Annual variation in magnetic storms. Abstract: Phys. Rev., Menasha, Wis., v. 37, No. 12, 1931 (1680-1681).

MELDAU, H. Zur Didaktik der Kreiselbewegungen. Ann. Hydrogr., Berlin, Jahrg. 59, Heft 5, 1931 (176-180).

MERCANTON, P. L. Rapport sur les observations de magnétisme terrestre faites au cours de la croisière du "Pourquoi Pas" durant l'été de 1929. Ann. hydrogr, Paris, Sér. 3, T. 10 (1930), 1931 (87-88). [Declination and dip were observed at five points in Scotland, Jan Mayen, Greenland, and Iceland, and samples of lava were collected in the volcanic regions and of basalt from the horizontal strata of the mountains surrounding the fiords for testing the hypothesis of the inversion of the dip in the course of the ages.]

MEYER, G. Magnetische Messungen über Basalteisensteinlagern in Oberhessen. Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 1, Heft 4, 1931 (420-431). [The tests made in the region of basalt rock showed that the method of magnetic investigation for locating deposits of ore and seams is not without chances of success. The ore-deposits lie in troughs between the basalt strata, from which a characteristic magnetic profile can be obtained.]

MOIDREY, J. DE. Études sur le magnétisme terrestre à Zi-ka-wei et Lu-kia-pang 1877-1927, résumées par J. de Moidrey, S. J. Fascicule VIII. Shanghai, Imprimerie de la Mission Catholique, 1931, 7 pp. 32 cm. [The present fascicule contains Études Nos. 37 and 38, entitled "Des éléments magnétiques au premier janvier" and "Suite des valeurs au premier janvier", respectively.]

MOUNT WILSON OBSERVATORY. Summary of Mount Wilson magnetic observations of sunspots for March and April, 1931. Pub. Astr. Soc. Pacific, San Francisco, Cal., v. 43, 1931 (221-222).

N., H. W. Magnetic storms and solar activity during 1930. Observatory, London, v. 54, No. 685, 1931 (163-165).

PARIS, BUREAU OF LONGITUDES. Annuaire pour l'an 1931 avec des notices scientifiques. Paris, Gauthier-Villars et C^ie (viii+693+A.151+B.24+C.8+D.70). 14 cm. [Contains isogonic charts of France for epoch January 1, 1924 and tables of magnetic declination at various stations in France reduced to same epoch. A table also of mean annual values of declination for various observatories in all parts of the world is given. Appendix A contains fourth part of article by G. Bigourdan on the Bureau of Longitudes in which historical sketch of magnetic work is included. Appendix B contains a general paper on atmospheric electricity by Ch. Maurain.]

REICH, H., UND R. SCHROEDER. Magnetische Untersuchung eines Basaltsteinbruchgeländes. Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 1, Heft 4, 1931 (432-436). [The area of a basalt quarry was investigated with the aid of a Schmidt vertical-field balance and values of Z ranging from $+1000\gamma$ to -600γ were obtained. A comparison with available geological information showed an excellent agreement between the two sets of data. The deposit was found to be magnetized in the direction of the Earth's magnetic field.]

ROMA, UFFICIO PRESAGI. Annuario 1931 (Anno IX). Roma, Istituto Poligrafico dello Stato, 1931 (303 con fig. e tav.). 18 cm. [Booklet issued by the Direzione Generale dei Servizi del Materiale e degli Aeroporti, Ministero dell' Aeronautica. It contains, besides meteorological and aerological information, a brief notice on terrestrial magnetism, with isomagnetic maps of the world for January 1922, values of declination and dip for stations in Italy and Italian colonies, reduced to epoch 1931.0, and isogonic map of Italy for epoch January 1, 1931.]

Schmidt, Ad. Das Variationshaus in Niemegk. (Im Anhang, Bericht Preuss. met. Inst. 1930.) Berlin, Veröff. met. Inst., No. 380, 1931 (59-66).

Seaton, S. L. Amateur radio as an aid to terrestrial-magnetic research. Q S T, Hartford, Conn., v. 15, No. 5, 1931 (9-10).

Stearn, N. H. A geomagnetic survey of the bauxite region in central Arkansas. Little Rock, Ark., Geol. Surv. Bull. 5, Nov. 15, 1930, 16 pp. Abstract: Colo. School Min. Mag., Golden, Colo., v. 21, No. 5, 1931 (30).

Stöcke, K. Magnetische Z-Variometermessung am Serpentin von Frankenstein in Schlesien. Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 1, Heft 4, 1931 (457-468). [An investigation of a serpentine deposit with the aid of a magnetic Z-balance showed that important conclusions regarding the extent of the deposit and its stratification can be drawn.]

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B—Terrestrial and Cosmical Electricity

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Belluigi, A. Ueber die Berechnung von deformierten elektromagnetischen Feldern in der geoelektrischen Prospektion. Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 1, Heft 4, 1931 (363-372).

Bock, R. Die elektrische Einrichtung des Variationshauses und des Absoluten Observatoriums in Potsdam. (Im Anhang, Bericht Preuss. met. Inst. 1930.) Berlin, Veröff. met. Inst., No. 380, 1931 (64-66).

Bogoaïvlensky, L. N. Etude de l'influence de quelques facteurs géophysiques sur les points de chute de la foudre. J. Physique et Le Radium, Paris, Sér. 7, T. 2, No. 4, 1931 (101-113). [L'auteur décrit les recherches sur la conductivité de l'air atmosphérique et du sol dans les endroits souvent frappés par la foudre. On a employé quatre procédés différents: méthode de la prospection radiométrique d'après le rayonnement pénétrant, les mesures de la conductivité électrique de l'air atmosphérique avec l'appareil de Gerdien, méthode de la prospection électrométrique avec un champ électrique artificiel, et méthode de la prospection électrométrique des champs électriques naturels. De ces quatre méthodes, les trois premières ont donné des résultats concluants qui démontrent que dans les endroits souvent frappés par la foudre, les grandeurs de l'intensité du rayonnement pénétrant terrestre et la conductivité électrique de l'air atmosphérique sont toujours plus élevées. Aux points où l'intensité de la radiation pénétrante atteint le maximum correspond la conductivité électrique du sol déterminée. Les expériences étaient faites sur les roches sédimentaires d'âge dévonien couvertes de dépots glaciaires sous forme d'amas de galets de roches cristallines.]

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Broxon, J. W. The residual ionization in air at new high pressures, and its relation to the cosmic penetrating-radiation. Phys. Rev., Menasha, Wis., v. 37, 1931 (1320-1337).

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PICK, W. H. Mammato-cumulus clouds and thunder-storms. Met. Mag., London, v. 66, No. 785, 1931 (106-109).

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SCHELLING, H. VON. Kosmische Strahlung und Weltraumstruktur. Naturw., Berlin, Jahrg. 19, Heft 27, 1931 (596).

SCHERHAG, R. Der Einfluss der meteorologischen Elemente auf die Gewitterbildung. Met. Zs., Braunschweig, Bd. 48, Heft 6, 1931 (201-207). [Abstracted from the first and second parts of the author's dissertation "Ueber die atmosphärischen Zustände bei Gewittern," Berlin, 1931.]

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STÖRMER, C. Ein Fundamentalproblem der Bewegung einer elektrisch geladenen Korpuskel im kosmischen Raume. Zs. Astroph., Berlin, Bd. 3, Heft 1, 1931 (31-52). [Es wird die Bewegung einer elektrisch geladenen Korpuskel diskutiert, die unter der kombinierten Wirkung eines magnetischen Dipols und einer Zentralkraft steht, die vom Dipol ausgeht und dem Quadrat der Entfernung umgekehrt proportional ist. Es weden zwei erste Integrale gefunden und mit ihrer Hilfe werden die Raumteile ermittelt, aus denen Bahnen nicht herausgelangen können. Ein wichtige Annäherung wird durch elliptische Funktionen vollständig integriert.]

TAGG, G. F. The earth-resistivity method of geoelectrical prospecting; some theoretical considerations. Min. Mag., London, v. 43, No. 3, 1930 (150-158).

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WELD, L. D. Progress in the analysis of cosmic-ray observations. Des Moines, Proc. Iowa Acad. Sci., v. 37, 1930 (294-296).

The results of a least-square adjustment of cosmic-ray observations. Phys. Rev., Menasha, Wis., v. 37, 1931 (1368-1369).

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BOYD, J. Geophysics applied to mining. Colo. School Min. Mag., Golden, Colo., v. 21, No. 5, 1931 (18, 38-39).

CURRIE, B. W. An unusual solar halo complex. Nature, London, v. 127, June 20, 1931 (925-926).

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ECKERSLEY, T. L. On the connection between the ray-theory of electric waves and dynamics. London, Proc. R. Soc., A, v. 132, 1931 (83-88). [Summary: A formal analogy between the quantum-theory and the transmission of electromagnetic waves in an ionized atmosphere is used to develop approximate solutions of the transmission of wireless waves round the Earth. These solutions are based on the approximate phase-integral methods of Bohr and Sommerfeld used in quantum-dynamics. The results are used to explain the effect of magnetic storms on short-wave transmission.]

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Götz, F. W. P., und R. Ladenburg. Ozongehalt der unteren Atmosphärenschichten. Naturw., Berlin, Jahrg. 19, Heft 18, 1931 (373-374).

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Hale, G. E. The spectrohelioscope and its work. Part III. Solar eruptions and their apparent terrestrial effects. Astroph. J., Chicago, Ill., v. 73, No. 5, 1931 (379-404). [In coöperative observations with the spectrohelioscope, to be made at many stations distributed around the world, occasional violent eruptions on the Sun's disc call for first attention. Several of these eruptions are followed after an average interval of about thirty-six hours by violent terrestrial magnetic storms and brilliant auroras. The principal theories regarding these phenomena, all of which ascribe them to the influence of solar disturbances, are briefly outlined. The paper includes a list of the 23 widely distributed observatories where spectrohelioscopes are already in use or will soon be erected. Other spectrohelioscopes will be available later at additional stations, thus making possible a comprehensive series of observations under the auspices of the International Astronomical Union.]

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Marten, W. Aus der Praxis der Sonnenstrahlungsmessungen am Meteorologischen Observatorium in Potsdam. (Im Anhang, Bericht Preuss. met. Inst. 1930.) Berlin, Veröff. met. Inst., No. 380, 1931 (153-162).

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Pickard, G. W. Note on the fifteen-month period in solar activity, terrestrial magnetism, and radio reception. New York, N. Y., Proc. Inst. Radio Eng., v. 19, No. 3, 1931 (353-355).

Rosseland, S. Astrophysik auf atomtheoretischer Grundlage. Berlin, Verlag von Julius Springer, 1931 (vi+252 mit 25 Abb.). 22 cm. *RM* 19.80; gebunden *RM* 21.20. [This book has been written with the double purpose of placing in the hands of physicists a brief introduction to the problems of astrophysics and of filling a gap in astronomical literature. Hence it is intended chiefly for astronomers who are concerned with the astrophysical applications of physics. No attempt has been made for completeness and many important problems, such as solar magnetism, have been only briefly touched upon. As the manuscript was completed in January 1930, literature appearing subsequent to 1929 could only partially be considered. The subject matter of the book falls under the following main headings: (1) Data of astrophysical observation (classes of spectra, temperature, brightness of stars, etc.); (2) physical basis for the problem of the interior of the stars; (3) hydrodynamics of the stars; (4) energetics and evolution history; (5) physics of the stellar atmosphere; (6) problem of the gaseous nebula.]

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The origin of the deep-water of the Pacific Ocean as indicated by the oceanographic work of the *Carnegie*. Beitr. Geophysik, Leipzig, Bd. 29, Heft 1, 1931 (1-21).

TEAR, J. D., AND E. J. LAWTON. Aircraft compass acceleration errors and their compensation. Gen. Elec. Rev., Schenectady, N. Y., v. 34, No. 4, 1931 (265-268).

TORRESON, O. W. The last cruise of the non-magnetic vessel *Carnegie*. Quarterly of Phi Pi Phi, Menasha, Wis., v. 7, No. 3, 1931 (219-228).

Penetrating the atom with beta- and gamma-rays. Science and Invention, New York, N. Y., v. 18, No. 12, 1931 (1090-1091, 1136 with 8 figs.)

VERIGO, A. B. The determination of the content of radio-active substances in rocks. Leningrad, Izv. Glav. Geofiz. Obs., No. 3, 1929 (3-10). [Russian text with English summary.]

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WHITMAN, W. G., AND M. A. TUVE. Biological effects of gamma-rays. Phys. Rev., Menasha, Wis., v. 37, No. 3, 1931 (331-332).

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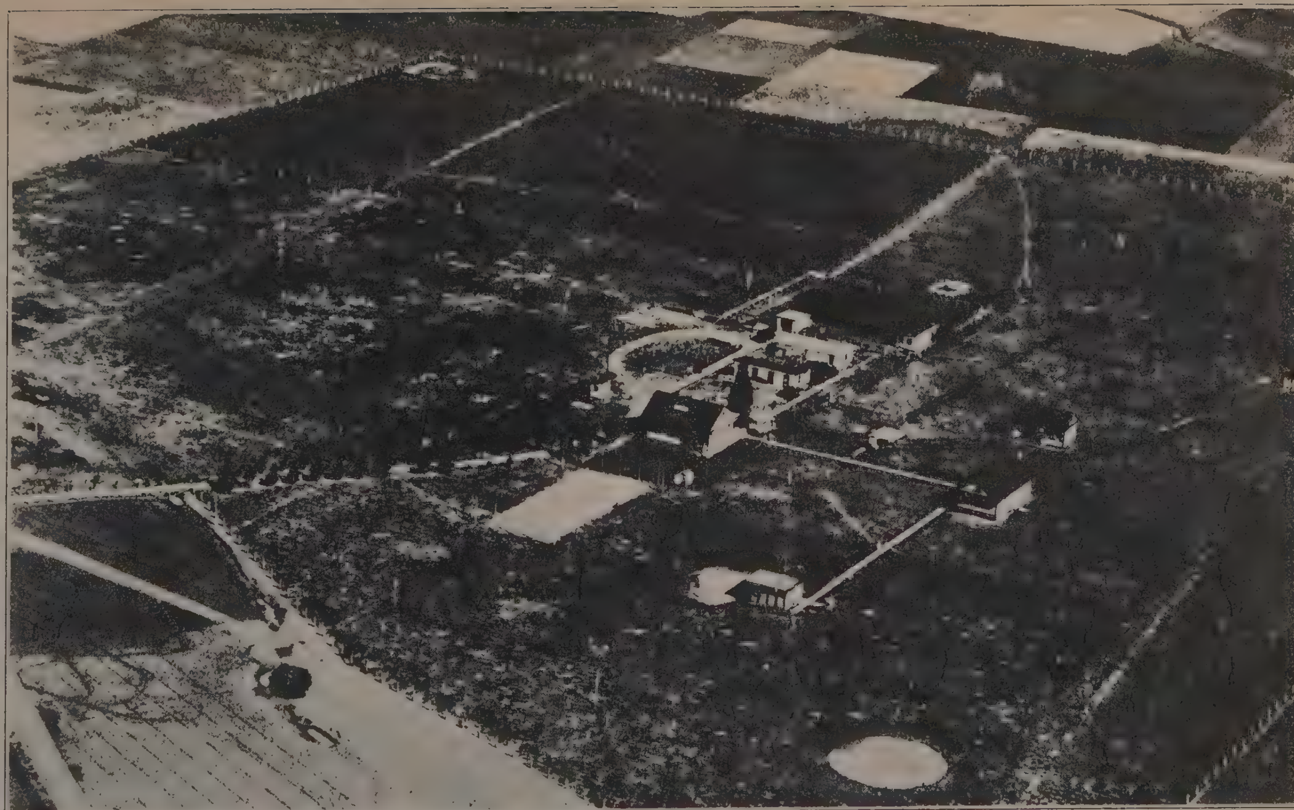
NOTICE

[Plate 6]



SITE AND BUILDINGS OF THE HUANCAYO MAGNETIC OBSERVATORY FROM THE AIR, APRIL 1931
(Photograph by Johnson-Shippee Photographic Expedition of American Geographical Society)

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 36 DECEMBER, 1931 No. 4

PRELIMINARY SUMMARY OF DATA ON THE PRESENT DISTRIBUTION OF MAGNETIC DECLINATION WITHIN THE ARCTIC ZONE[1]

BY BORIS P. WEINBERG

The determinations of the magnetic elements in the arctic regions are so irregularly distributed over the territory as well as in time that it is very difficult to find their distribution for a definite epoch in a manner sufficiently trustworthy—even for the declination, which up to the present has been determinined about three times as often as the inclination or the horizontal component.

For solving this problem I had to operate by the method of successive approximations relating to an element e and to its secular variation (annual change) e'. I used largely the method of reducing the values of e and e' to angularly equidistant points by means of preliminary values (also successively corrected) of the gradients $de/d\phi$ and $de/d\lambda$ of the element e, and similar gradients of e' for latitude ϕ and longitude λ.

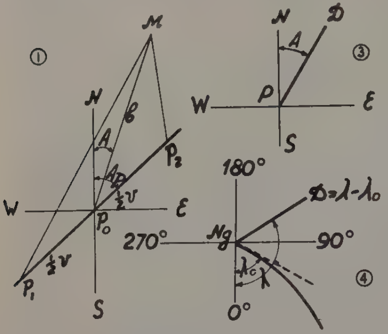
The method of reduction here summarized has been developed as the result of my experience in reducing to 1925.0 all the magnetic determinations in USSR and adjacent countries.[2]

The compilation of all magnetic determinations in the arctic, for a catalogue for the Second International Polar Year, and the special researches of V. V. Beketova on the diurnal change of the magnetic elements in the polar regions, were only in the initial stages for inclination and horizontal intensity, and about one-half the work completed for declination, at the time of the polar flight of "LZ127" in July 1931. As the second approximations of the annual changes of declination differ considerably from the first approximations only for some regions, and as the distribution of declination is much more important for practical purposes than the distribution of inclination and horizontal intensity, I decided not to wait until the calculations necessary for the final stages of the reduction were completed, and to give in this article the second-

[1]Abstract of a paper to be published in J. Geophys., Leningrad, No. 2, 1931, in English with a Russian résumé.

[2]B. P. Weinberg, Catalogue of magnetic determinations over the territory of USSR and adjacent countries from 1556 to 1926. Leningrad (1929).

approximation distribution of the annual changes of declination and the first-approximation distribution of declination itself. The work of constructing the corresponding maps was greatly lessened by paying attention to the following peculiarities of the magnetic pole and of the geographic pole



FIGS. 1, 3, and 4—Diagrammatic sketches to illustrate derivation of equations

(1) Let the linear velocity of the magnetic pole P_0 (Fig. 1) be v kilometers per year with an approximate value of 0.90, and the azimuth of its motion A_p approximating 45° east of north. Then the annual change D' of D at a point C kilometers from the mean position of the magnetic pole P_0 at a certain moment t_0 can be expressed by equation (1)

$$(1) \quad D' = \text{arc sin}\left\{[v \sin (A_p - A)]/2[C^2 + v^2/4 - vC \cos (A_p - A)]^{1/2}\right\} + \text{arc sin}\left\{[v(\sin A_p - A)/2[C^2 + v^2/4 + vC \cos (A_p - A)]\right\}$$

where A denotes the azimuth of the line MP_0. It may be mentioned that the first arc sin has to be taken lying between 90° and 180° if

$$(2) \quad C < (v/2) \cos (A_p - A)$$

The equation (1) leads to the distribution of the isolines near the pole represented by Figure 2 and permits tracing the initial directions and the following form of the isolines in the regions from the magnetic pole outward to places for which the annual change may be supposed to be more or less known.

(2) The azimuth A (Fig. 3) of the initial direction of an isogonic relating to a definite value D of the declination and issuing from the magnetic pole is

$$(3) \quad A = D + 180°$$

east declination being considered positive, west declination negative, and azimuths positive from north to east and negative from north to west.

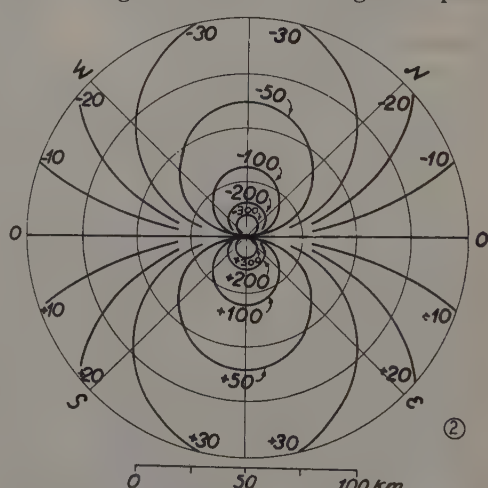


FIG. 2—Sketch showing theoretical isopors for magnetic declination within 100 kilometers of the magnetic pole due to its motion, values being expressed in units of 0°.01

(3) If λ_0 (Fig. 4) be the longitude of the meridian for which the declination is 0° in the immediate proximity of the geographic north pole N_g, the longitude of the meridian which is there tangent to the isogonic relating to a definite value D of the declination, is

$$(4) \quad \lambda = D + \lambda_0$$

From the summary of the second-approximation values at equidistant points for $\phi=87°$, $\phi=83°$, and $\phi=79°$, I found $\lambda_0=60°$ east, which it is interesting to note agrees reasonably well with the value $\lambda=50°$, derived from the chart of magnetic meridians prepared by Haussmann for the flight of the "LZ127" and based on first-approximation values of D' found by us in 1929 when I had the pleasure of coöperating a few days with him on this question.

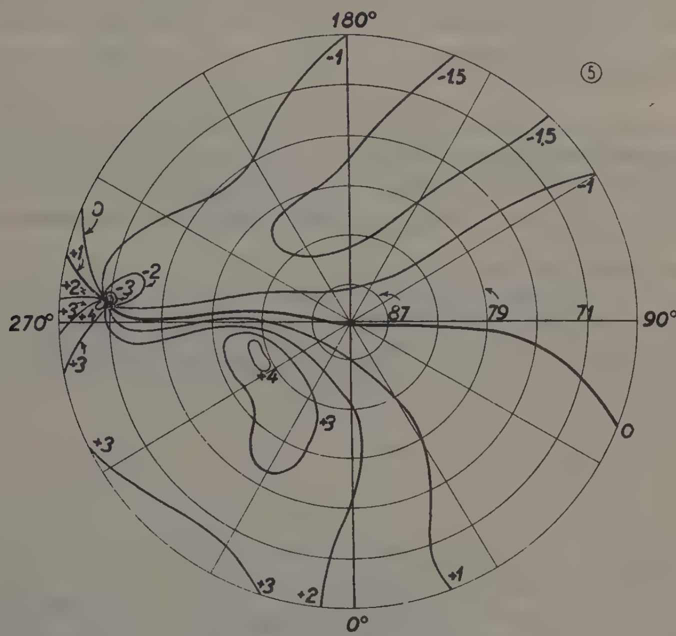


FIG. 5—Mean isopors of magnetic declination in the arctic regions for the period 1890 to 1930, values being expressed in units of 0°.1

The results are summarized in Figures 5 and 6 and in Table 1. Figure 5, representing the isolines of annual change (isopors), expressed in tenths of a degree per year, may be adopted for the period 1890 to 1930 and probably for some 10 years later.* Figure 6 represents the isogonics for 1930. Table 1 gives in tabular form the data from which the charts were drawn, the upper line of each subdivision giving the declination, and the lower line the annual change in hundredths of a degree. If the lower line contains two numbers, the first gives the mean annual change which may be adopted for the interval 1820 to 1930, and the second for the interval 1920 to 1930. The values in parentheses are interpolated. The values of D which are underscored with a double

*Note by Editor—The widely scattered distribution of observations made at irregular intervals justifies these generalizations over much of the region discussed, but it should be borne in mind that accelerations of rate are very considerable in some parts particularly near foci of rapid change. One such lies at present in northwestern Europe and probably extends into the arctic east of Greenland. In this connection see H. W. Fisk, Isopors and isoporic movements (Comptes-Rendus de l'Assemblée de Stockholm, Union Geod. Geoph. Intern., Sect. Terr. Mag. Electr., Bull. No. 8, 280-292, 1931). Reference for comparison of isomagnetic charts may also be made to H. W. Fisk, Isomagnetic charts of the arctic area (Pub. Nation. Res. Council, Trans. Amer. Geophys. Union, 12th Annual Meeting, 134-139, June 1931).

line are certain within 0°.2 to 0°.5, and those of D' within 0°.01; those values of D underscored with a single line are certain within 1° or 2°, and those of D' within 0°.02 to 0°.03 per year. The others may be still less certain.

In the preparation of Table 1 the tabular differences, $\Delta\phi$ and $\Delta\lambda$, are taken as 4°, but the initial value of the longitude is 1° east for latitudes 87°, 79°, and 71°, and 3° east for latitudes 90°, 83°, 75° and 67°. The reason for this arrangement is to avoid ambiguity in computing the values of D or D' for any point (ϕ,λ) lying within the triangle

$$\begin{array}{ccc} (\phi_1,\lambda_1) & \text{———} & (\phi_2,\lambda_2) \\ \diagdown & & \diagup \\ & (\phi_3,\lambda_3) & \end{array} \quad \text{or} \quad \begin{array}{ccc} & (\phi_3,\lambda_3) & \\ \diagup & & \diagdown \\ (\phi_1,\lambda_1) & \text{———} & (\phi_2,\lambda_2) \end{array} \tag{5}$$

Such an ambiguity is unavoidable if we have to deal with a rectangular net of equidistant points instead of a triangular one.[3]

[3]B. P. Weinberg, Application of the theory of surfaces to the problems of finding isopoints and tracing isolines. J. Geophys., 3, 19-42 (1926). [Russian with English abstract.]

Table 1 —Values of magnetic declination, D, and of its annual change, D', in the arctic for approximate epoch 1930

(The values given for D are in units of 1°, those for D' are in units of 0°.01)

Longitude east of Greenwich

Latitude North	Value	1°	359°	357°	355°	353°	351°	349°	347°	345°	343°	341°	339°	337°	335°	333°	331°	329°	327°	325°	323°	321°	319°	317°	315°	313°	311°	309°	307°	305°	303°
90°	D		(- 61)		(- 65)		(- 69)		(- 73)		(- 77)		(- 81)		(- 85)		(- 89)		(- 93)		(- 97)		(-101)		(-105)		(-109)		(-113)		(-117)
	D'		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)
87	D	(- 33)		(- 36)		-18.3		-39.2		(- 45)		(- 53)		(- 60)		(- 67)		(- 73)		(- 79)		(- 84)		(- 89)		(- 93)		(- 98)		(-102)	
	D'	(+ 10)		(+ 10)		(+ 10)		(+ 11)		(+ 11)		(+ 11)		(+ 11)		(+ 12)		(+ 12)		(+ 12)		(+ 12)		(+ 12)		(+ 12)		(+ 11)		(+ 11)	
83	D		(- 28)		(- 32)		(- 36)		(- 40)		(- 43)		(- 46)		(- 50)		(- 53)		-56.8		-61.1		(- 66)		(- 70)		(- 74)		-90.3		-80.0
	D'		(+ 21)		(+ 22		(+ 23)		(+ 24)		(+ 26)		(+ 28)		(+ 29)		(+ 31)		(+ 32)		(+ 34)		(+ 35)		(+ 36)		(+ 37)		(+ 38)		(+ 39)
79	D	-23.0		-22.7		(- 17)		-10.8		(- 27)		-36.4		(- 41)		(- 45)		(- 50)		(- 55)		(- 59)		(- 63)		(- 67)		(- 71)		(- 76)	
	D'	(- 21)		(+ 22)		(+ 23)		(+ 24)		(+ 25)		(+ 27)		(+ 29)		(+ 31)		(+ 33)		(+ 34)		(+ 33)		(+ 32)		(+ 31)		(+ 30)		(+ 29)	
75	D		-19.7		-22.2		-31.0		-35.0		-36.4		-40.1		-37.9		(- 44)		(- 47)		(- 51)		(- 55)		(- 59)		(- 62)		(- 66)		-70.5
	D'		(+ 21)		(+ 22)		(+ 23)		(+ 24)		(+ 25)		(+ 26)		(+ 27)		(+ 28)		(+ 29)		(+ 28)		(+ 27)		(+ 26)		(+ 25)		(+ 24)		(+ 25)
71	D	-19.8		-20.7		-21.9		-23.5		(-27.4)		(-30.2)		-31.3		-38.7		(-38.8)		(-41.3)		(-44.4)		(-48.0)		-51.4		-59.8		-64.1	
	D'	(+ 17)		(+ 18)		(+ 20)		(+ 22)		(+ 24)		(+ 26)		+ 27		(+ 28)		(+ 29)		(+ 29)		(+ 29)		(+ 29)		(+ 28)		(+ 28)		+ 28	
67	D		-17.9		-20.6		-22.8		-24.4		-23.1		-34.0		-30.5		-38.9		-38.0		-39.2		-47.6		-51.2		-60.2		-57.4		-54.8
	D'		(+ 17)		(+ 20)		(+ 22)		(+ 24)		+ 25		(+ 28)		+ 30		+ 32		(+ 33)		+ 34		+ 33		(+ 32)		(+ 32)		(+ 31)		(+ 31)

Longitude east of Greenwich

Latitude North	Value	299°	297°	295°	293°	291°	289°	287°	285°	283°	281°	279°	277°	275°	273°	271°	269°	267°	265°	263°	261°	259°	257°	255°	253°	251°	249°	247°	245°	243°	241°
90°	D	(-121)		(-125)		(-129)		(-133)		(-137)		(-141)		(-145)		(-149)		(-153)		(-157)		(-161)		(-165)		(-169)		(-173)		(-177)	
	D'	(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)	
87	D		(-111)		(-116)		(-122)		(-128)		(-134)		(-140)		(-146)		(-152)		(-158)		(-164)		(-170)		(-177)		(+176)		(+169)		(+163)
	D'		(+ 10)		(+ 9)		(+ 8)		(+ 7)		(+ 5)		(+ 3)		(+ 2)		(+ 1)		(0)		(- 1)		(- 2)		(- 3)		(- 4)		(- 5)		(- 6)
83	D	-85.6		-88.6		-95.7		-106.4		-107.8		(-113)		-115.6		(-132)		(-144)		(-158)		(-173)		(+174)		(+162)		(+150)		(+140)	
	D'	(+ 39)		(+ 38)		(+ 36)		(+ 34)		(+ 31)		(+ 27)		(+ 20)		(+ 12)		(+ 6)		(0)		(- 4)		(- 7)		(- 9)		(- 11)		(- 12)	
79	D		-90.6		-90.4		-94.2		-97.4		-109.4		(-119)		(-130)		-137.2		-142.7		-176.3		+167.0		+152.9		+137.1		+116.9		+93.1
	D'		(+ 29)		(+ 28)		(+ 29)		(+ 28)		(+ 26)		(+ 23)		(+ 20)		(+ 10)		(- 1)		(- 7)		(- 10)		(- 12)		(- 13)		(- 13)		(- 13)
75	D	-82.9		-81.9		-87.2		-94.3		-98.5		-103.0		-107.6		-124.3		-151.3		-162.6		-159.6		+142.8		+130.7		+92.5		+96.8	
	D'	(+ 26)		+ 26		(+ 26)		(+ 25)		(+ 23)		+ 20		+ 13		(+ 4)		- 15		- 18		(- 17)		- 15		(- 14)		(- 13)		- 12	
71	D		-69.2		-71.6		-84.6		-97.5		-93.3		-95.5		-87.1		-108.9		-178.2		+158.9		+90.7		(+91.0)		(+80.0)		(+68.6)		+66.6
	D'		(+ 27)		(+ 26)		(+ 25)		(+ 24)		(+ 23)		(+ 22)		(+ 18)		(+ 4)		(- 80)		(- 17)		(- 13)		(- 10)		(- 8)		(- 7)		(- 7)
67	D	(-57.0)		-56.4		(-57.4)		(-57.0)		-55.2		-59.7		-53.6		-49.5		-11.5		+11.0		+62.6		+55.6		+49.2		+51.3		+49.6	
	D'	(+ 30)		(+ 29)		(+ 28)		(+ 29)		(+ 30)		+ 31		(+ 30)		(+ 27)		(+ 24)		(+ 20)		(+ 15)		(+ 10)		+ 8		+ 4		+ 2	

Longitude east of Greenwich

Latitude North	Value	237°	235°	233°	231°	229°	227°	225°	323°	221°	219°	217°	215°	213°	211°	209°	207°	205°	203°	201°	199°	197°	195°	193°	191°	189°	187°	185°	183°	181°	179°
90°	D		(+175)		(+171)		(+167)		(+163)		(+159)		(+155)		(+151)		(+147)		(+143)		(+139)		(+135)		(+131)		(+127)		(+123)		(+119
	D'		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1
87	D	(+157)		(+152)		(+147)		(+143)		(+138)		(+134)		(+130)		(+126)		(+123)		(+119)		(+115)		(+111)		(+108)		(+104)		(+101)	
	D'	(- 7)		(- 7)		(- 8)		(- 8)		(- 9)		(- 10)		(- 10)		(- 10)		(- 11)		(- 11)		(- 11)		(- 11)		(- 11)		(- 11)		(- 12)	
83	D		(+122)		(+114)		(+106)		(+ 99)		(+ 94)		(+ 90)		(+ 85)		(+ 80)		(+ 75)		(+ 70)		(+ 65)		(+ 60)		(+ 56)		(+ 52)		(+ 48
	D'		(- 13)		(- 14)		(- 14)		(- 14)		(- 15)		(- 15)		(- 16)		(- 16)		(- 17)		(- 17)		(- 18)		(- 18)		(- 17)		(- 17)		(- 17
79	D	(+ 93)		(+ 87)		(+ 81)		(+ 76)		(+ 70)		(+ 64)		(+ 59)		(+ 54)		(+ 49)		(+ 44)		(+ 40)		(+ 36)		(+ 33)		(+ 30)		(+ 27)	
	D'	(- 14)		(- 14)		(- 14)		(- 14)		(- 14)		(- 14)		(- 14)		(- 14)		(- 14)		(- 15)		(- 15)		(- 15)		(- 15)		(- 16)		(- 16)	
75	D		+72.2		(+ 65)		(+ 59)		(+ 54)		(+ 50)		(+ 46)		(+ 42)		(+ 38)		(+ 35)		(+ 32)		(+ 29)		(+ 26)		(+ 23)		(+ 20)		(+ 16
	D'		(- 12)		(- 11)		(- 11)		(- 11)		(- 11)		(- 11)		(- 12)		(- 12)		(- 12)		(- 13)		(- 13)		(- 13)		(- 14)		(- 14)		(- 15
71	D	+60.7		+56.3		+47.5		+45.8		+44.4		+39.6		+38.0		+37.6		+30.8		+31.8		+28.2		+23.8		+20.0		+17.0		+13.2	
	D'	- 6		- 6		- 6		- 6		- 6		- 6		- 6		(- 7)		- 7		- 8		- 9		(- 10)		(- 11)		(- 12)		- 13	
67	D		+49.0		+48.5		+45.4		+42.0		+37.1		+32.9		+30.9		+27.9		+26.0		+22.6		+20.6		+17.7		+15.1		+12.2		+ 8.
	D'		- 1		- 2		- 2		- 2		- 2		- 3		- 4		- 5		(- 6)		(- 7)		(- 8)		(- 9)		(- 10)		(- 11)		- 12

If the values of D for these three points are D_1, D_2, and D_3, and the changes for 4° of longitude and for 4° of latitude inside our triangle are

$$\Delta_\phi D = [(D_1 + D_2)/2 - D_3] \tag{6}$$

$$\Delta_\lambda D = (D_2 - D_1) \tag{7}$$

The value of D at a point (ϕ, λ) may be assumed to be equal to

$$D_{\phi,\lambda} = D + \Delta_\phi D\ (\phi - \phi_3)/240 + \Delta_\lambda D(\lambda - \lambda_3)/240 \tag{8}$$

In (8) the quantities $(\phi - \phi_3)$ and $(\lambda - \lambda_3)$ are expressed in minutes of arc, the first difference always being taken as positive and the second difference being taken with regard to its sign.

At the geographic north pole a different value of the declination is assigned to each meridian, in accordance with the principle of equation (4), from which at that point we have $D = (\lambda - \lambda_0)$ in which λ_0 is the meridian tangent to the zero-isogonic.

Table 1.—Values of magnetic declination, D, and of its annual change, D', in the arctic for approximate epoch 1930—Continued

(The values given for D are in units of 1°, those for D' are in units of 0°.01)

Longitude east of Greenwich

Value	1°	3°	5°	7°	9°	11°	13°	15°	17°	19°	21°	23°	25°	27°	29°	31°	33°	35°	37°	39°	41°	43°	45°	47°	49°	51°	53°	55°	57°	59°	61°
D		(- 57)		(- 53)		(- 49)		(- 45)		(- 41)		(- 37)		(- 33)		(- 29)		(- 25)		(- 21)		(- 17)		(- 13)		(- 9)		(- 5)		(- 1)	
D'		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)	
D	(- 33)		(- 30)		(- 27)		(- 25)		(- 22)		(- 19)		(- 16)		(- 13)		(- 9)		(- 3)		+ 5.6		+ 8.2		+12.0		(+13.8)		+17.8		+19.8
D'	(+ 10)		(+ 10)		(+ 9)		(+ 9)		(- 8)		(+ 8)		(+ 7)		(+ 7)		(+ 7)		(+ 6)		(+ 6)		(+ 6)		(+ 5)		(+ 5)		(+ 4)		(+ 4)
D		-25.5		(-21.8)		-17.8		-14.2		-10.6		- 5.7		- 3.7		- 0.1		+ 2.9		+ 4.1		(+ 9.1)		(+12.8)		(+16.6)		+22.6		+23.6	
D'		(+ 20)		(+ 18)		(+ 16)		(+ 14)		(+ 13)		(+ 12)		(+ 11)		(+ 10)		(+ 9)		(+ 8)		(+ 7)		(+ 6)		(+ 7 + 5)		(+ 7 + 4)		(+ 6 + 4)	
D	-23.0		-20.1		-12.3		- 9.9		- 6.3		- 2.5		- 1.6		+ 2.4		(+ 5.7)		(+ 9.0)		+12.5		+14.7		+17.1		+20.9		+21.5		+24.1
D'	(+ 21)		(+ 19)		+ 17		+ 15		+ 14		+ 13		+ 12		+ 11		(+ 10)		(+ 9)		(+ 9)		(+ 8)		+ 8		+ 7		+ 7		(+ 6)
D		-17.7		-13.2		-10.9		- 6.4		- 3.7		(- 0.4)		+ 2.1		+ 3.8		+ 8.8		+11.5		+15.1		+16.0		+18.6		+20.0		+22.6	
D'		+ 20		+ 18		(+ 16)		+ 14		+ 13		(+ 12)		(+ 11)		(+ 10)		+ 9		+ 9		+ 8		+ 8		+ 7		+ 7		+ 7	
D	-19.8		-19.2		(-12.1)		- 7.4		- 5.1		- 1.4		+ 1.3		+ 4.6		+ 7.2		+ 9.2		+15.1		+15.9		+16.5		+18.9		+20.0		+21.9
D'	(+ 17)		(+ 15)		(+ 14)		(+ 13)		+ 12		+ 12		+ 11		+11 +10		+11 +10		+10 + 9		(+10 + 8)		(+10 + 8)		+ 9 + 7		+ 9 + 7		+ 9 + 6		+ 9 + 5
D		-15.9		-11.2		-10.8		- 6.1		- 1.8		- 0.6		+ 2.6		+ 5.3		+ 7.9		+10.2		+12.3		+14.6		+16.0		+17.8		+19.0	
D'		(+ 14)		+ 13		+ 12		+ 10		+11 +10		+10 + 9		+10 + 9		+10 + 9		+ 9 + 9		+ 9 + 8		+ 9 + 8		+ 8 + 7		+ 8 + 6		+ 8 + 5		+ 8 + 2	

Longitude east of Greenwich

Value	63°	65°	67°	69°	71°	73°	75°	77°	79°	81°	83°	85°	87°	89°	91°	93°	95°	97°	99°	101°	103°	105°	107°	109°	111°	113°	115°	117°	119°	121°	123°
D	(+ 3)		(+ 7)		(+ 11)		(+ 15)		(+ 19)		(+ 23)		(+ 27)		(+ 31)		(+ 35)		(+ 39)		(+ 43)		(+ 47)		(+ 51)		(+ 55)		(+ 59)		(+ 63)
D'	(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)
D		+22.4		+24.2		+28.4		+31.2		+34.2		(+38.2)		(+41.6)		+45.2		(+47.2)		+47.6		(+ 53)		(+ 56)		(+ 59)		(+ 62)		(+ 65)	
D'		(+ 3)		(+ 3)		(+ 2)		(+ 2)		(+ 1)		(+ 1)		(0)		(- 1)		(- 1)		(- 2)		(- 3)		(- 3)		(- 4)		(- 5)		(- 5)	
D	+24.0		(+26.8)		+31.1		+29.6		+31.1		+34.9		(+35.8)		+35.6		+38.3		+39.0		+39.6		+39.5		+39.7		(+39.0)		(+38.1)		+37.1
D'	(+ 6 + 3)		(+ 5 + 2)		(+ 5 + 2)		(+ 5 + 2)		(+ 4 + 1)		(+ 3 + 1)		(+ 3 0)		(0 0)		(- 2 - 1)		(- 2)		(- 2)		(- 3)		(- 4)		(- 5)		(- 6)		(- 7)
D		+25.0		+26.8		+28.4		(+28.4)		(+28.9)		(+29.3)		(+29.6)		(+29.8)		(+30.0)		+28.1		+28.7		(+28.0)		(+26.7)		(+25.3)		(+23.8)	
D'		(+ 6)		(+ 5)		(+ 4)		(+ 3)		(+ 2)		(+ 1)		(0)		(- 1)		(- 2)		(- 3)		(- 4)		(- 5)		(- 6)		(- 7)		(- 8)	
D	+25.2		+25.6		+25.4		+27.6		+29.9		(+28.5)		+26.8		(+27.0)		+26.0		(+23.9)		(+22.0)		(+19.8)		+19.1		+11.3		(+ 9.2)		+ 5.3
D'	+ 7		+ 6		(+ 6)		(+ 5)		+ 4		(+ 4)		(+ 3)		(+ 2)		+ 1 + 2		(0 + 1)		(- 1 0)		(- 2)		(- 4 - 5)		(- 6 - 7)		(- 7 - 9)		(- 8 -10)
D		+23.4		+24.2		+25.6		(+25.9)		+25.1		+23.9		+22.2		(+21.0)		(+19.0)		+15.6		+13.4		(+ 9.0)		+ 3.9		+ 2.3		- 2.8	
D'		+ 8 + 4		+ 7 + 3		+ 7 + 2		(+ 6 + 1)		+ 5 + 1		+ 4 + 1		(+ 3 0)		(+ 2 - 1)		(+ 1 - 2)		(0 - 3)		- 2 - 4		(- 4 - 5)		(- 6 - 6)		(- 7 - 8)		- 8 -10	
D	+ 19.1		+21.5		+21.4		+21.8		+21.7		(+21.2)		+20.1		+19.4		+15.0		+16.3		+ 9.7		+ 6.2		+ 1.2		- 1.9		- 5.3		- 9.5
D'	(+ 7 0)		+ 7 - 2		+ 6 - 2		+ 6 - 3		(+ 5 - 3)		(+ 5 - 4)		+ 4 - 4		+ 3 - 5		(+ 2 - 5)		(0 - 6)		(- 2 - 7)		(- 4 - 8)		(- 6 - 9)		(- 7 -10)		(- 8 -11)		- 9 -12

Longitude east of Greenwich

Value	125°	127°	129°	131°	133°	135°	137°	139°	141°	143°	145°	147°	149°	151°	153°	155°	157°	159°	161°	163°	165°	167°	169°	171°	173°	175°	177°	179°	181°	183°	185°
D		(+ 67)		(+ 71)		(+ 75)		(+ 79)		(+ 83)		(+ 87)		(+ 91)		(+ 95)		(+ 99)		(+103)		(+107)		(+111)		(+115)		(+119)		(+123)	
D'		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)		(- 1)	
D	(+ 67)		(+ 70)		(+ 73)		(+ 75)		(+ 77)		(+ 79)		(+ 82)		(+ 84)		(+ 86)		(+ 88)		(+ 90)		(+ 92)		(+ 95)		(+ 98)		(+101)		(+104)
D'	(- 6)		(- 6)		(- 7)		(- 7)		(- 8)		(- 8)		(- 8)		(- 9)		(- 9)		(- 9)		(- 10)		(- 10)		(- 10)		(- 11)		(- 12)		(- 11)
D		+35.6		(+ 35)		(+ 35)		(+ 34)		(+ 34)		(+ 35)		(+ 36)		(+ 37)		(+ 38)		(+ 39)		(+ 40)		(+ 42)		(+ 45)		(+ 48)		(+ 52)	
D'		(- 8)		(- 9)		(- 10)		(- 11)		(- 12)		(- 12)		(- 13)		(- 14)		(- 14)		(- 15)		(- 15)		(- 15)		(- 16)		(- 17)		(- 17)	
D	(+22.2)		+21.2		+16.0		+12.2		(+ 12)		(+ 11)		(+ 12)		(+ 13)		(+ 14)		(+ 16)		(+ 18)		(+ 20)		(+ 22)		(+ 25)		(+ 27)		(+ 30)
D'	(- 9)		(- 10)		-12 -11		-13 -12		-14 (-13)		(- 14)		(- 15)		(- 16)		(- 17)		(- 18)		(- 18)		(- 17)		(- 17)		(- 16)		(- 16)		(- 16)
D		+ 3.2		(+ 1.2)		- 1.0		- 1.5		- 2.1		- 3.0		- 1.9		+ 0.8		+ 1.6		+ 3.2		+ 6.1		+ 8.3		+11.7		(+ 16)		(+ 20)	
D'		(-10 -11)		(-11 -12)		(-12 -13)		-14 -15		-15 -17		-16 -18		(-16 -18)		-17 -19		(-18 -19)		(- 18)		(- 18)		(- 17)		(- 16)		(- 15)		(- 14)	
D	- 4.9		- 6.6		- 8.0		- 8.6		- 8.5		- 8.3		- 6.2		(- 5.5)		- 5.7		- 1.4		+ 0.1		+ 3.0		+ 5.8		+ 8.3		+13.2		+17.0
D'	- 9 -11		-10 -12		-11 -13		-12 -14		-12 -16		-13 -17		-14 -18		(-15 -18)		(-16 -17)		-15 -17		-14 -17		-14 -16		-14 -15		- 14		- 13		(- 12)
D		(- 9.2)		(- 9.4)		- 8.4		(- 8.8)		(- 7.9)		(- 6.8)		(- 5.5)		(- 4.0)		- 0.7		- 2.3		- 0.2		(+ 4.8)		+11.1		+ 8.0		+12.2	
D'		(- 9 -13)		(- 9 -13)		(-10 -14)		(-10 -15)		(-11 -16)		(-12 -17)		(-13 -17)		(-14 -16)		-15 -16		- 16		- 15		(- 14)		- 13		- 12		(- 11)	

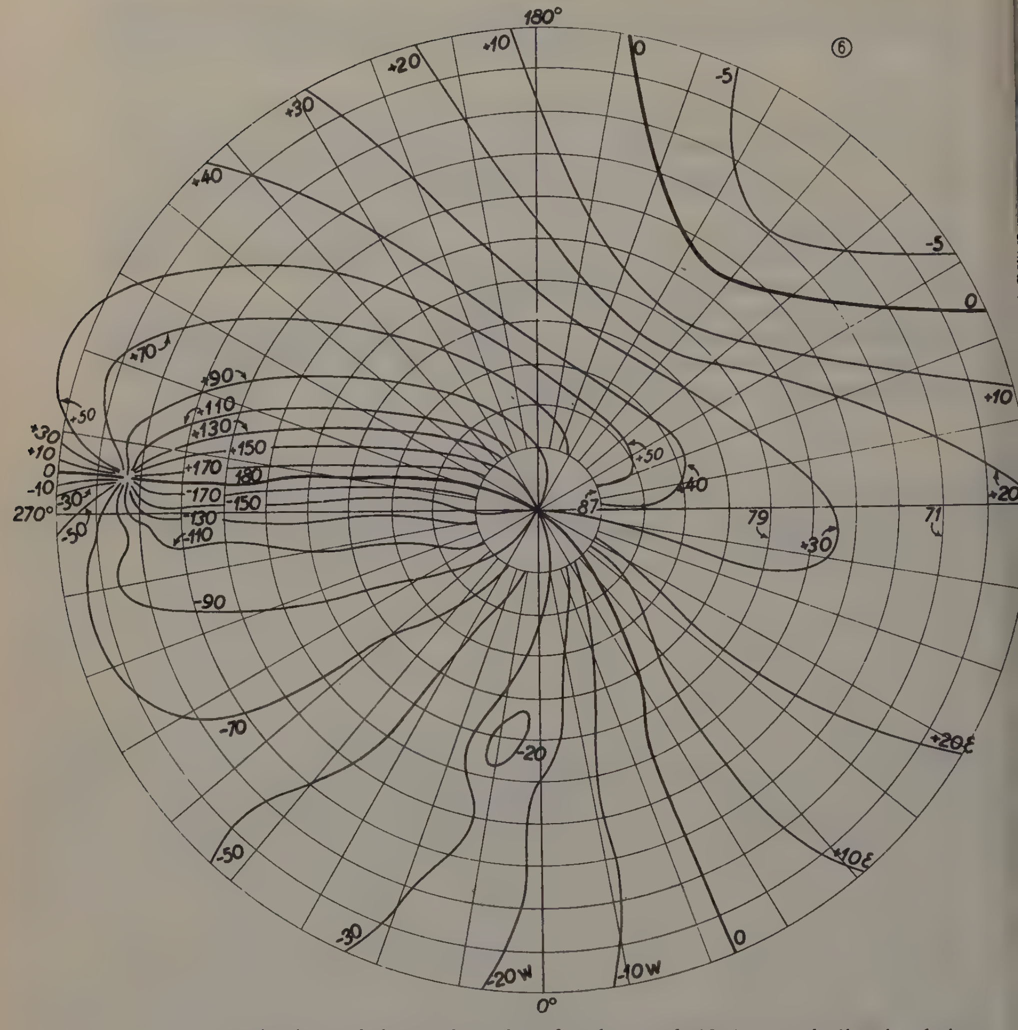


FIG. 6—Isogonic chart of the arctic regions for the epoch 1930, east declination being reckoned as positive (+) and west declination as negative (−)

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TEST-DEFLECTIONS FOR VARIOMETERS AND MAGNETOGRAPHS

By George Hartnell

1. *Introduction*—This paper develops equations describing the deflections of a suspended magnet produced by a deflecting-magnet fixed in any desired position. The distances are assumed large enough to render distribution-effects negligible. The equations are applied individually to a declination (D), horizontal-intensity (H), and vertical-intensity (Z) variometer, and to an assembly of these three variometers, which constitute a magnetograph. Under the conditons assumed, the equations furnish a convenient means of testing magnetic instruments. Since such instruments contain one or more magnets as essential parts, their response to magnetic forces as theoretically deduced provides a criterion of their merit.

2. *Axes of reference*—A set of right-handed rectangular axes is chosen in which the x-axis points magnetically north, the y-axis magnetically east, and the z-axis vertically downward. The origin is taken at the center of the D, H, or Z recording-magnet, as required.

3. *Suspended magnet*—The symbols used pertaining to the suspended magnet are:

M_s = magnetic moment of suspended magnet and also suspended magnet;
λ_s, μ_s, ν_s = direction-cosines of suspended magnet;
θ = angle between axis of M_s and x-axis;
ψ = angle of inclination of axis of M_s to xy-plane;
$\lambda_s = \cos\psi\cos\theta$; $\mu_s = \cos\psi\sin\theta$; $\nu_s = \sin\psi$;
θ_0 = particular angle of equilibrium;
δ = angle through which head has been turned;
$\tau = \delta - \theta$ = torsion in fiber;
h = torsion-factor;
ϵ = angluar value of 1 mm on magnetogram in radians;
v = angular deviation from position of equilibrium for D–variometer;
v' = angular deviation from position of equilibrium for H-variometer;
$u = -v/\epsilon$ = deflection of D-magnet in mm on magnetogram;
$u' = -v'/\epsilon$ = deflection of H-magnet in mm on magnetogram;

4. *Deflecting-magnet*—

M_a = magnetic moment of deflecting-magnet and also deflecting-magnet;
a, b, c = coordinates of center of deflecting-magnet;
d = distance between centers of M_s and M_a;
λ_a, μ_a, ν_a = direction-cosines of axis of M_a;
a/d, b/d, c/d = direction-cosines of center of M_a;
α = angle between line d and x-axis;
β = angle between line d and xy-plane;
ϕ = angle between axis of M_a and x-axis;
ω = angle between axis of M_a and xy-plane;
$\lambda_a = \cos\omega\cos\phi$; $\mu_a = \cos\omega\sin\phi$; $\nu_a = \sin\omega$;
$a/d = \cos\alpha\cos\beta$; $b/d = \sin\alpha\cos\beta$; $c/d = \sin\beta$.

5. *Fundamental angles*—δ = angle between axis of M_a and line d; ξ = angle between axis of M_s and line d; η = angle between axis of M_a and axis of M_s. All the mutual deflection-properties, and distribution-coefficients as well, are functions of these three fundamental angles, thus

$$\cos\delta = (a/d)\lambda_a + (b/d)\mu_a + (c/d)\nu_a$$
$$\cos\xi = (a/d)\lambda_s + (b/d)\mu_s + (c/d)\nu_s$$
$$\cos\eta = \lambda_a\lambda_s + \mu_a\mu_s + \nu_a\nu_s$$

Transforming these equations

(1) $$\cos\delta = \cos\beta\cos\omega\cos(\alpha-\phi) + \sin\beta\sin\omega$$

(2) $$\cos\xi = \cos\beta\cos\psi\cos(\alpha-\theta) + \sin\beta\sin\psi$$

(3) $$\cos\eta = \cos\omega\cos\psi\cos(\phi-\theta) + \sin\omega\sin\psi$$

6. *Fundamental angles for D- and H-variometers*—In the D- and H-variometers, the magnet M_s is level, so that $\psi = 0$, and θ is the variable angle. Then

(4) $$\cos\delta = \cos\beta\cos\omega\cos(\alpha-\phi) + \sin\beta\sin\omega$$

(5) $$\cos\xi = \cos\beta\cos(\alpha-\theta)$$

(6) $$\cos\eta = \cos\omega\cos(\phi-\theta)$$

7. *Fundamental angles for Z-variometer*—In this case, $\theta = 0$, ψ is variable, and

(7) $$\cos\delta = \cos\beta\cos\omega\cos(\alpha-\phi) + \sin\beta\sin\omega$$

(8) $$\cos\xi = \cos\beta\cos\psi\cos\alpha + \sin\beta\sin\psi$$

(9) $$\cos\eta = \cos\omega\cos\psi\cos\phi + \sin\omega\sin\psi$$

8. *Other symbols*—V = mutual potential-energy of M_a and M_s; H = horizontal intensity; Z = vertical intensity; $F = M_a/d^3$ = field-intensity of magnet M_a. Other symbols will be explained in the text.

9. *Mutual potential-energy of two magnets*—When distribution-effects are neglected, the general expression for the mutual potential-energy of two magnets is (DC[1], p. 6)

(10) $$V = (M_aM_s/d^3)(-3\cos\delta\cos\xi + \cos\eta)$$

We shall develop the equations first for the D-variometer, in which case θ is the variable angle. The torque exerted by M_a on M_s is

(11) $$-\delta V/\delta\theta = FM_s\left(3\cos\delta\frac{\delta\cos\xi}{\delta\theta} - \frac{\delta\cos\eta}{\delta\theta}\right) \qquad (DC\text{, eq. 14})$$

The torque exerted by the horizontal intensity, H, on M_s is

(12) $$-M_sH\sin\theta + h(\delta-\theta) \qquad (HIV^2\text{, eq. 55})$$

the D-variometer being of the unifilar type. However, we assume the effect of torsion has been allowed for, so that mm on the magnetogram

[1](DC) is used to denote reference "Distribution-coefficients of magnets" by G. Hartnell, U. S. Coast Geod. Surv., Spec. Pub. No. 157.

[2](HIV) is used to denote reference "Horizontal-intensity variometers" by G. Hartnell, U. S. Coast Geod. Surv., Spec. Pub. No. 89.

are directly convertible into arc. Hence the torque represented by (12) becomes

(13) $$-M_sH \sin \theta$$

10. *Equations for D-variometer*—Inserting the derivatives of (5) and (6) in (11), we obtain for the mutual torque

(14) $$-\delta V/\delta\theta = FM_s[3 \cos \delta \cos \beta \sin (\alpha-\theta) - \cos \omega \sin (\phi-\theta)]$$

Since the magnet M_s is in equilibrium, the sum of (14) and (13) is zero

(15) $$FM_s[3 \cos \delta \cos \beta \sin (\alpha-\theta) - \cos \omega \sin (\phi-\theta)] - M_sH \sin \theta = 0$$

Expanding (15), dividing through by $M_s \cos \theta$, and solving for $\tan \theta$

(16) $$\tan \theta = \frac{F(\cos \omega \sin \phi - 3 \cos \beta \cos \delta \sin \alpha)}{F(\cos \omega \cos \phi - 3 \cos \beta \cos \delta \cos \alpha) - H}$$

The expression $F(\cos \omega \cos \phi - 3 \cos \beta \cos \delta \cos \alpha)$ in the denominator of (16) either vanishes or is very small, so that within the limits of experimental error, it is negligible. Hence, remembering that $\theta=0$ is the equilibrium-position of M_s when M_a is away, the deflection-equation for the D-variometer is

(17) $$\tan v = (F/H)(3 \cos \beta \cos \delta \sin \alpha - \cos \omega \sin \phi)$$

11. *Centers of magnets in horizontal or xy-plane*—When the centers of the magnets lie in the horizontal plane, $\beta=0$ and $\cos \delta = \cos \omega \cos (\alpha-\phi)$. Equation (17) becomes

(18) $$\tan v = (F/H) \cos \omega [3 \cos (\alpha-\phi) \sin \alpha - \sin \phi]$$

Expanded, this is

(19) $$\tan v = (F/H) \cos \omega [3 \sin \alpha \cos \alpha \cos \phi + \sin \phi (3 \sin^2 \alpha - 1)]$$

The presence of $\cos \omega$ outside the bracket indicates that the deflection varies as the cosine of the angle which the axis of M_a makes with the xy-plane, α and ϕ remaining unchanged, that is, when the axis of M_a moves in the vertical plane defined by α and ϕ.

When M_a is east with north end east, on the y-axis, $\phi=\alpha=90°$. The deflection is then

(20) $$\tan v = (2F/H) \cos \omega$$ (magnet inclined in yz-plane)

When $\alpha=0$, $\phi=90°$, M_a being north with north end east

(21) $$\tan v = (-F/H) \cos \omega$$ (magnet inclined in plane parallel to yz-plane)

When the center of M_a lies on y-axis, and the axis of M_a moves in a plane parallel to xz-plane, $\alpha=90°$, $\phi=0$, $\tan v=0$. Also when the axis of M_a lies in xz-plane, $\alpha=\phi=0$, $\tan v=0$. In all cases, there is no deflection when the axis of M_a is vertical, the center being in the xy-plane. The physical significance is that the magnetic moment may be treated as a vector, and so may be resolved into components. The vertical component of M_a is $M_a \sin \omega$, which produces no deflection, while the horizontal and effective component is $M_a \cos \omega$, which may again be

resolved into components $M_a \cos \omega \cos \phi$ and $M_a \cos \omega \sin \phi$ parallel to the x- and y-axes, respectively.

12. *Axes and centers of magnets in xy-plane*—In this case, $\cos \omega = 1$ and

(22) $$\tan v = (F/H)\,[3 \sin \alpha \cos \alpha \cos \phi + \sin \phi\,(3 \sin^2 \alpha - 1)]$$

For $\phi = \alpha = 90°$

(23) $$\tan v = 2F/H \qquad (A\text{-position})$$

For $\alpha = 0$, $\phi = 90°$

(24) $$\tan v = -F/H \qquad (B\text{-position})$$

13. *Errors due to setting magnet: A-position*—As equations (23) and (24) are of frequent use in scale-value determinations. it will be of interest to ascertain the error due to angular misplacements of the deflecting-magnet. Differentiating equation (22) with respect to ϕ

(25) $$\delta\,(\tan v) = (F/H)\,[-3 \sin \alpha \cos \alpha \sin \phi + (3 \sin^2\alpha - 1)]\ \delta\,(\sin \phi)$$

Let $\phi = 90° + \phi'$, $\sin \phi = \cos \phi'$. Hence in the A-position for which $\alpha = 90°$

(26) $$\delta\,(\tan v) = (2F/H)\ \delta\,(\cos \phi')$$

This is the error due to setting the axis of the deflecting-magnet along the bar or along the y-axis. The error will amount to one per cent when $\phi' = 8°.1$.

Differentiating (22) partially with respect to α

(27) $$\delta\,(\tan v)/\delta\alpha = (F/H)\,[(3 \cos^2\alpha - 3 \sin^2\alpha) \cos \phi + \sin \phi\,(6 \sin \alpha \cos \alpha)]$$

Let $\alpha = 90 + \alpha'$, $\sin \alpha = \cos \alpha'$, $\cos \alpha = -\sin \alpha'$. For $\phi = 90°$, we have

(28) $$\delta\,(\tan v)/\delta\alpha' = -(6F/H) \sin \alpha' \cos \alpha'$$

and neglecting quantities of second order

(29) $$\delta\,(\tan v)/\delta\alpha' = (2F/H)\,(-3 \sin \alpha') = (2F/H)\,[3\delta\,(\cos \alpha')]$$

This will amount to an error of one per cent when $\alpha' = 2°.7$. Hence the error due to setting the center of the deflecting-magnet on the y-axis, or in the magnetic prime vertical is three times as great as the error corresponding to the setting of the axis of the magnet.

14. *Errors due to setting magnet: B-position*—In the B-position $\alpha = 0$, $\phi = 90°$. Let $\phi = 90° + \phi'$, or $\sin \phi = \cos \phi'$, and make $\alpha = 0$ in equation (25)

(30) $$\delta\,(\tan v) = -(F/H)\ \delta\,(\cos \phi')$$

As before, this will amount to one per cent when $\phi' = 8°.1$. When $\phi = 90°$ and α is small, we have from equation (27)

(31) $$\delta\,(\tan v) = -(F/H)\,[6\delta\,(\cos \alpha')]$$

This amounts to one per cent when $\alpha = 1°.35$. Thus the error due to missetting the center of the deflecting-magnet in the magnetic meridian is six times as large as the error corresponding to setting the axis of the magnet parallel to the magnetic prime-vertical. In all these cases there is a decrease in the deflection, so that the computed magnet-moment of the deflecting-magnet is always smaller than its true value.

15. *Zero deflections for magnets in xy-plane*—The condition for zero deflection is obtained from equation (22)

(32) $$3 \sin \alpha \cos \alpha \cos \phi + (3 \sin^2 \alpha - 1) \sin \phi = 0$$

or

(33) $$\tan \phi = -(3 \sin \alpha \cos \alpha)/(3 \sin^2\alpha - 1) = 3 \tan \alpha/(1 - 2 \tan^2\alpha)$$

This is independent of the distance d. We see that $\phi = 0$ when $\alpha = 0$, that is, there is no deflection when the axis and center of M_a are in the meridian. Also $\phi = 0$ when $\alpha = 90°$, that is, there is no deflection when the center of M_a is on the y-axis and its axis is parallel to the x-axis, or magnetic meridian. These properties have been previously mentioned in section 11. If α is given, ϕ can be computed from equation (33). If ϕ is given, α can be computed from the equation

(34) $$\tan \alpha = (1/4 \tan \phi)\ (-3 \mp \sqrt{9 + 8 \tan^2\phi})$$

which is derived from (33) by solving for $\tan \alpha$. Thus when the deflecting-magnet is placed anywhere in the xy-plane, its axis may be so turned, by changing the angle ϕ, that the suspended magnet is not deflected. In other words, the suspended magnet is undeflected when its axis lies along a line of force from the deflecting-magnet.

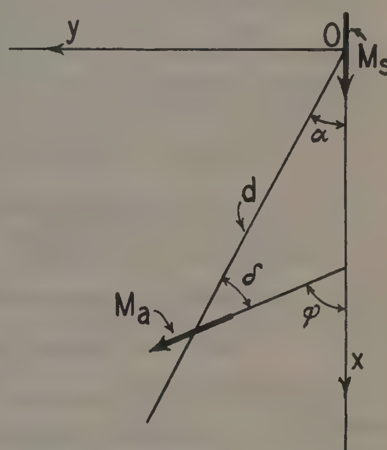


FIG. 1—Diagram illustrating lines of force from deflecting-magnet

16. *Lines of force*—Further information about the lines of force from the deflecting-magnet M_a may be obtained by considering Figure 1. Since M_s is undeflected, it lies along a line of force from M_a, and since $\theta = 0$ it lies along the x-axis. We seek a relation between α and δ. The torque exerted by M_a being $= 0$ we have, from equation (14), when $\omega = \beta = 0$

(14) $$\text{Torque} = FM_s\ [(3 \cos \delta \sin (\alpha - \theta) - \sin (\phi - \theta)] = 0$$

or, since $\theta = 0$, and $\phi = \delta + \alpha$ from Figure 1

(35) $$3 \cos \delta \sin \alpha = \sin \phi = \sin (\delta + \alpha)$$
$$\tan \alpha = (1/2) \tan \delta$$

Equation (35) is one form of the equation of the lines of force. If R is the field-intensity of M_a at the center of M_s, we have, resolving along and perpendicular to the line d, $R \cos \alpha$ and $R \sin \alpha$. Also, the components of M_a along and perpendicular to d are $M_a \cos \delta$ and $M_a \sin \delta$. The field at O due to $M_a \cos \delta$ is

(36) $$2M_a \cos \delta/d^3$$

and is in the direction of M_s to M_a along line d. The field due to $M_a \sin \delta$ is

(37) $$(M_a/d^3) \sin \delta$$

and is perpedicular to d. The resultant intensity is

$$R=F\sqrt{4\cos^2\delta+\sin^2\delta}=F\sqrt{3\cos^2\delta+1}=F\sqrt{4-3\sin^2\delta} \tag{38}$$

and is in the direction of the x-axis, or in a direction such that

$$\tan \alpha=(1/2)\tan \delta \tag{35}$$

Another convenient equation for the lines of force is obtained by considering that

$$\tan \alpha=d\,[\delta(\delta)/\delta(d)] \tag{39}$$

in which δ ( ) is a differential. From (35) and (39) we have $2\delta\,(\sin\delta)/\sin\delta=\delta\,(d)/d$, which integrated is

$$d=C\sin^2\delta \tag{40}$$

The lines of force are oval curves passing through the center of M_a, and are symmetrical about its axis. Equations (35), (38), and (40) are well-known results and are given here for reference.

17. *Field of magnet in rectangular coordinates*—To determine the field-intensity of a simple magnet, it is sometimes convenient to use rectangular coordinates, referred to the magnet itself. The potential at a point in the field is (see *DC*, p. 14)

$$V=N[(1/r_1)-(1/r_2)]=N\left\{1/[(x-l_a)^2+y^2]^{1/2}-(1/[(x+l_a)^2+y^2]^{1/2}\right\} \tag{41}$$

in which N is the strength of the pole, r_1 and r_2 are the distances of the point (x, y) from the poles whose distance apart is $2l_a$; $d^2=x^2+y^2$. The small quantity $l_a{}^2/d^2$ is dropped.

$$V=N\left\{[(1-2xl_a/d^2)^{-1/2}/d]-[(1+2xl_a/d^2)^{-1/2}/d]\right\}$$

$$V=N(2xl_a/d^3)=M_ax/d^3=M_a\cos\delta/d^2=M_ax/(x^2+y^2)^{3/2} \tag{42}$$

Since $M_a=2Nl_a$. The intensity X in the direction of the axis of the magnet is

$$X=-\delta V/\delta x=(M_a/d^5)\,(2x^2-y^2) \tag{43}$$

The intensity Y perpendicular to the axis of the magnet is

$$Y=-\delta V/\delta y=3M_axy/d^5 \tag{44}$$

The resultant intensity is

$$R=(X^2+Y^2)^{1/2}=(4x^4+5x^2y^2+y^4)^{1/2} \tag{45}$$

which is identical with (38) when transformed into polar coordinates. Using the polar form

$$V=M_a\cos\delta/d^2 \tag{42}$$

we obtain for the intensity along d

$$-\delta V/\delta(d)=2M_a\cos\delta/d^3 \tag{36}$$

as in equation (36), and for the intensity perpendicular to d

$$-\delta V/d\delta(\delta)=M_a\sin\delta/d^3 \tag{37}$$

18. *Characteristic deflections at constant distance*—Resuming equation (22) we observe that when the center and axis of M_a move with the line d at constant distance (move with a bar for example) $\phi = \alpha$ and

$$\tan v = (2F/H) \sin \alpha \tag{46}$$

The deflection varies from the maximum $2F/H$ to 0 as the bar is turned from $\alpha = 90°$ to $\alpha = 0$. When the axis of M_a is perpendicular to the bar, or to the line d, $\phi = 90° + \alpha$, $\sin \phi = \cos \alpha$, $\cos \phi = -\sin \alpha$ and (19) becomes

$$\tan v = -(F/H) \cos \alpha \tag{47}$$

Here $\tan v$ varies from F/H for $\alpha = 0$ to 0 for $\alpha = 90°$. When in (19) $\alpha = 90°$ as for A-position

$$\tan v = (2F/H) \sin \phi \tag{48}$$

so that as the magnet is rotated, the deflection varies from $2F/H$ to 0. Likewise when $\alpha = 0$

$$\tan v = -(F/H) \sin \phi \tag{49}$$

and as the magnet is rotated, the deflection varies from $-F/H$ to 0. In fact, when M_a in the xy-plane rotates around a vertical axis, the deflection always varies according to a sine- or cosine-law. For, if in equation (22) we let $3 \sin \alpha \cos \alpha = E_1 = E \sin e$, $3 \sin^2 \alpha - 1 = E_2 = E \cos e$, $E^2 = E_1^2 + E_2^2$, then $\tan e = (3 \sin \alpha \cos \alpha)/(3 \sin^2 \alpha - 1)$ and

$$\tan v = (FE/H) \sin (\phi + e) \tag{50}$$

which is a sine- or cosine-function. As remarked in section 15, v is made zero by turning M_a until $\phi = -e$.

19. *Characteristic deflections for deflecting-magnet parallel to y-axis*—When the center of M_a moves in a circle, with its axis always parallel to y-axis ϕ, $= 90°$, so that equation (22) becomes

$$\tan v = (F/H)\,(3 \sin^2\alpha - 1) \qquad (A\text{-type, constant distance}) \tag{51}$$

The deflection-curve is the lower curve shown in Figure 2 for $M_a = 10{,}000$, $d = 200$ cm, $H = 0.1856$ c. g. s. The deflection is zero when

$$3 \sin^2\alpha - 1 = 0, \text{ that is for } \alpha = 34° \, 16' \tag{52}$$

The tangent to the curve is

$$\delta (\tan v)/\delta\alpha = (6F/H) \sin \alpha \cos \alpha \tag{53}$$

Hence maxima are found at 90° and 270°, and minima are found at 0°, 180°, and 360°. Differentiating (53)

$$\delta^2 \tan v/\delta\alpha^2 = (6F/H)\,(\cos^2\alpha - \sin^2\alpha) \tag{54}$$

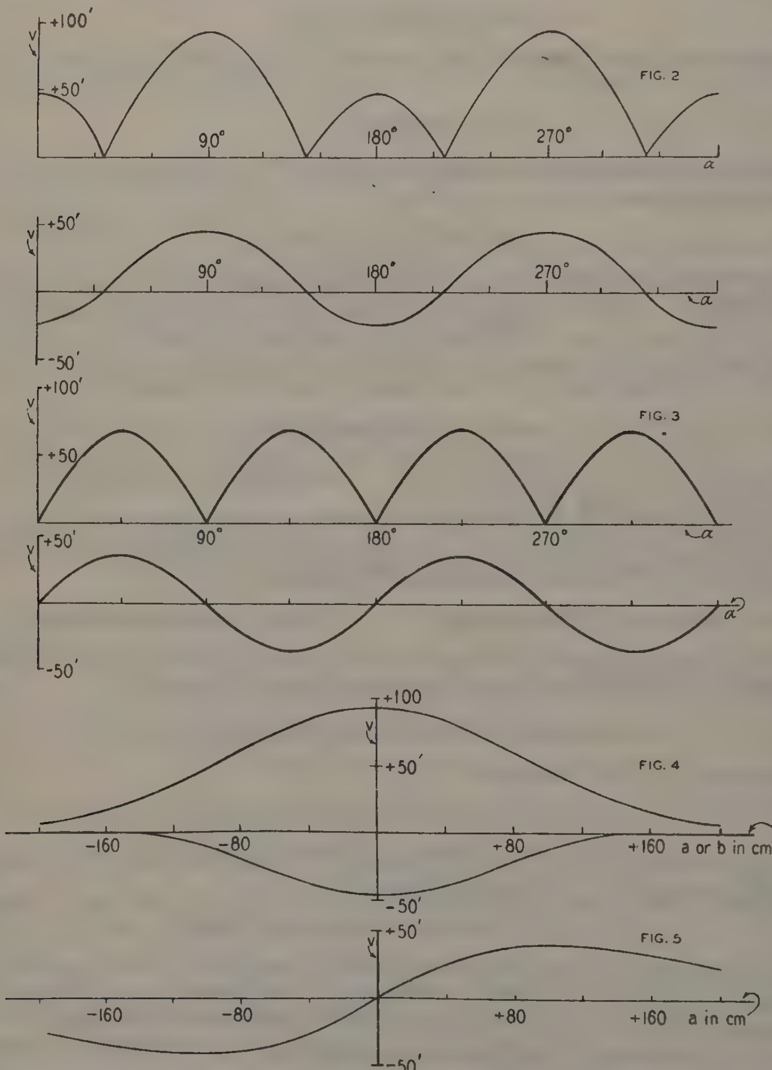
Hence flex points occur at 45°, 135°, 225° and 315°. The upper curve in Figure 2 for $M_a = 10{,}000$, $d = 200$ cm, $H = 0.1856$ c. g. s. shows the deflections when the deflecting-magnet is reversed in every position.

20. *Characteristic deflections with deflecting-magnet parallel to x-axis*—When $\phi = 0$ in equation (22)

$$\tan v = (3F/H) \sin \alpha \cos \alpha = (3/2)\,(F/H) \sin 2\alpha \qquad (B\text{-type, constant distance}) \tag{55}$$

The lower curve in Figure 3 shows shows the deflection-curve for $M_a = 10{,}000$, $D = 200$ cm, and $H = 0.1856$ c. g. s. It has maxima at 45° and 225°, and minima at 135° and 315°. The flex points are at 0°, 90°, 180°, 270° and 360° The double deflections are shown by the upper curve in Figure 3.

Thus we have two types of deflection-curves, at constant distance. We call the deflection-curve represented by equation (51) the A-type deflection-curve at constant distance. This type arises when the de-



FIGS. 2, 3, 4, and 5—Deflection-curves computed for $M_a = 10{,}000$, $d = 200$ cm, $D = 200$ cm, and $H = 0.1856$ c. g. s. (2, deflecting-magnet parallel to y-axis; 3, deflecting-magnet parallel to x-axis; 4, perpendicular type; 5, parallel type)

flecting-magnet is always parallel to the y-axis. The deflection-curve represented by equation (55) we call the B-type at constant distance. The largest deflection is found in the A-curve, while the next largest is found in the B-type curve. The maximum deflections are in the ratio of 4:3:2. As seen from equation (22) all deflections of two magnets in the same plane at constant distance are compounded of these two types of curves.

21. *Characteristic deflection-curves, perpendicular type*—When the axis of the deflecting-magnet M_a is kept perpendicular to the x-axis, and is moved along a line parallel to the x-axis, $\phi=90°$, $b=$constant, d and a are variable, and equation (22) then becomes

(56) $$\tan v=(M_a/d^3H)\ (3\sin^2\alpha-1)=(M_a/d^3H)\ (2\sin^2\alpha-\cos^2\alpha)$$

The constant coordinate b of the center of M_a is distinguished by the capital letter D. We have the relations $d^2=D^2+a^2$, $\sin\alpha=a/d$, $\cos\alpha=D/d$, whence (56) becomes

(57) $$\tan v=(M_a/d^5H)\ (2D^2-a^2)=(M_a/H)\ (2D^2-a^2)/(D^2+a^2)^{5/2}$$
(primary perpendicular-type)

The deflection-curve is shown in Figure 4 for $M_a=10{,}000$ $D=200$ cm, $H=0.1856$ c. g. s. in the upper curve. Tan v is zero when

(58) $$(2D^2-a^2)=0, \text{ that is, when } a=D\sqrt{2}$$

Denoting the variable part of equation (57) by f,

(59) $$f=(2D^2-a^2)/(D^2+a^2)^{5/2}$$

and differentiating with respect to a

(60) $$\delta f/\delta a=(3a^3-12D^2a)/(D^2+a^2)^{7/2}$$

For a maximum or minimum, this is zero, hence the maximum and minimum correspond to

(61) $$a=0 \text{ (maximum) and } a=2D \text{ (minimum)}$$

For a flex point $\delta^2f/\delta a^2=0$ and

(62) $$a^2=D^2(27\pm\sqrt{665})/8$$

When the axis of M_a is kept parallel to the y-axis and is moved along a line perpendicular to the x-axis, $\phi=90°$ and $a\equiv D$. The relations then are $d^2=(D^2+b^2)$, $\sin\alpha=b/d$, and $\cos\alpha=D/d$. Using these in (56)

(63) $$\tan v=M_a/H\ (2b^2-D^2)/(D^2+b^2)^{5/2}$$ (perpendicular type, secondary)

The deflection-curve is shown in Figure 4 for $M_a=10{,}000$, $D=200$ cm, and $H=0.1856$ c. g. s. in the lower curve. Tan v is zero when

(64) $$b=(1/2)\sqrt{2}D$$

Denoting the variable part of (63) by f

(65) $$f=(2b^2-D^2)/(D^2+b^2)^{5/2}$$

Differentiating this with respect to b,

(66) $$\delta f/\delta b=(9D^2b-6b^3)/(D^2+b^2)^{7/2}$$

Tan v is a maximum or minimum when

(67) $$b=0 \text{ (maximum) and } b=(1/2)\sqrt{6}D \text{ (minimum)}$$

For a flex point, $\delta^2 f/\delta b^2=0$, so $b^2=D^2(6\pm\sqrt{30})/4$. The primary and secondary perpendicular-types of deflection-curves are shown in Figure 4.

22. *Characteristic deflection-curves, parallel type*—When the center of M_a moves along a line parallel to x-axis, and its axis is kept parallel to x-axis, we have the relations $\phi=0$, $b=D$, $\sin\ \alpha=b/d$, and $\cos\ \alpha=a/d$, which substituted in (22) give

(68) $$\tan v=(3M_a/H)\,[Da/(D^2+a^2)^{5/2}] \qquad \text{(parallel type)}$$

Likewise, if M_a is moved along a line perpendicular to x-axis, and has its axis always parallel to the x-axis, we have the relations $\phi=0$, $a=D$, $\sin\ \alpha=b/d$, $\cos\ \alpha=D/d$, which used in (22) gives

(69) $$\tan v=(3M_a/H)\,[Db/(D^2+b^2)^{5/2}] \qquad \text{(parallel type)}$$

Equations (68) and 69) are identical in form. Thus we get the same type of deflection-curve whether we move the deflecting-magnet parallel to the meridian east or west of the D-variometer, or parallel to the prime vertical north or south of the D-variometer, provided the axis of the deflecting-magnet is north-south. Considering (68), $\tan v=0$ when $a=0$, and representing the variable part of (68) by $f=Da/(D^2+a^2)^{5/2}$ and differentiating,

(70) $$\delta f/\delta a=D\ (D^2-4a^2)/(D^2+a^2)^{7/2}$$

Hence for a maximum,

(71) $$a=(1/2)D$$

Differentiating again $\delta^2 f/\delta a^2=[5a(4a^2-3D^2)]/(D^2+a^2)^{9/2}$ and flex points occur at

(72) $$a=0 \text{ and at } a=(1/2)\sqrt{3}D=0.866\ D$$

The parallel-type curve is shown in Figure 5 for $M_a=10{,}000$, $D=200$ cm, and $H=0.1856$ c. g. s. These types were named with the idea that, the deflections being small, the magnets in xy-plane were perpendicular or parallel to each other. This does not always hold in other planes.

23. *Center of deflecting-magnet in yz-plane*—The general equation is (17), which combined with (1) gives on expansion

(73) $$\tan v=(F/H)\ [(3\ \sin^2\alpha\ \cos^2\beta-1)\cos\omega\ \sin\phi+3\ \cos^2\beta\ \sin\alpha\ \cos\alpha\ \cos\omega\ \cos\phi+3\ \sin\beta\ \cos\beta\ \sin\alpha\ \sin\omega]$$

When the center of M_a lies in yz-plane, $\alpha=90°$ and in this case

(74) $$\tan v=(F/H)\ [(3\ \cos^2\beta-1)\cos\omega\ \sin\phi+3\ \sin\beta\ \cos\beta\ \sin\omega]$$

When the axis of M_a lies in yz-plane parallel to y-axis, $\omega=0$, $\phi=90°$, and then

(75) $$\tan v=(F/H)\ (3\ \cos^2\beta-1) \qquad (A\text{-type, constant distance})$$

Equation (75) is of the same form as (51), and has all the characteristic

properties of the A-type at constant distance. When M_a is vertical, $\omega=90°$, and

(76) $\tan v=(3F/H)\sin\beta\cos\beta$ (B-type, constant distance)

Equation (76) is of the same form as (55), and has all the characteristics of the B-type deflection-curve at constant distance. When the center of M_a with axis parallel to y-axis is moved along a line parallel to z-axis at constant distance D from the axis, we have the relations $d^2=D^2+c^2$, $\sin\beta=c/d$, and $\cos\beta=D/d$, which when substituted in (75) gives

(77) $\tan v=(M_a/H)[(2D^2-c^2)/(D^2+c^2)^{5/2}]$ (primary perpendicular-type)

When the axis of M_a is parallel to y-axis and its center is moved along a line parallel to y-axis at constant distance D, the relations are $d^2=D^2+b^2$, $\sin\beta=c/d=D/d$, and $\cos\beta=b/d$, whence

(78) $\tan v=(M_a/H)[(2b^2-D^2)/(D^2+b^2)^{5/2}]$ (secondary perpendicular-type)

This is the same as (63), and the deflection-curve has the same properties.

When M_a is vertical, or parallel to z-axis, and moves along a line parallel to z-axis, the relations are $d^2=D^2+c^2$, $\sin\beta=c/d$, and $\cos\beta=D/d$, whence from (76)

(79) $\tan v=(3M_a/H)[Dc/(D^2+c^2)^{5/2}]$ (parallel type)

This is the same in form as (69), and is used in determining the induction-factor of the long magnet of a magnetometer. Tan v is a maximum when

(80) $c=(1/2)D$

Thus, we see that the A-type and the primary and secondary perpendicular-types arise when the deflecting-magnet is horizontal, or parallel to y-axis, while the B-type and the parallel type arise when the deflecting-magnet is vertical or parallel to z-axis. All the deflections in the yz-plane at constant distance are compounded of types A and B, and all the deflections produced by the deflecting magnet as it moves along a line parallel and perpendicular to the z-axis are compounded of the parallel type and the respective perpendicular primary or secondary type.

When $\omega=0$ and $\phi=0$, $\tan v=0$, so that no deflections are produced when the center of the deflecting-magnet is moved around in the yz-plane, and the magnet is at the same time perpendicular to that plane.

24. *Center of deflecting-magnet in xz-plane*—When the center of M_a lies in the xz-plane, $\alpha=0$ and equation (73) then becomes

(81) $\tan v=-(F/H)\cos\omega\sin\phi$

When M_a is perpendicular to xz-plane, $\omega=0$, $\phi=90°$, and

(82) $\tan v=-F/H$

That is, if M_a is perpendicular to xz-plane, the deflection depends solely on the distance, and is constant when the center of M_a describes a circle. If the axis of M_a lies in the xz-plane, $\phi=0$, and $\tan v=0$ for all positions of M_a in the xz-plane.

25. *Axis and center of magnet in plane parallel to xy-plane*—Let the given plane be parallel to xy-plane, and at a given distance below it, the magnet M_a being in the given plane, $\omega=0$, and from equation (73)

$$\tan v=(F/H)\,[(3\cos^2\beta\sin^2\alpha-1)\sin\phi+3\cos^2\beta\sin\alpha\cos\alpha\cos\phi)] \tag{83}$$

26. *Plane parallel to xy-plane, deflections at constant distance*—If the center of the deflecting-magnet moves in a circle, and its axis lies in a vertical plane through the origin, d is constant and $\phi=\alpha$, and

$$\tan v=(F/H)\,(3\cos^2\beta-1)\sin\alpha \tag{84}$$

and $\tan v$ varies from zero to $(F/H)\,(3\cos^2\beta-1)$.

If ϕ is perpendicular to α, $\phi=90°+\alpha$, $\sin\phi=\cos\alpha$, $\cos\phi=-\sin\alpha$, and then (83) becomes

$$\tan v=-(F/H)\cos\alpha \tag{85}$$

This varies from $-F/II$ to zero, and is independent of β, the angle of inclination of the center of M_a to the xy-plane. Equations (84) and (85) should be compared with (46) and (47).

27. *Plane parallel to xy-plane, two types of deflections*—Equation (83) shows that here again we have two types of deflections at constant distance, according as $\phi=0$ or $\phi=90°$. When $\phi=90°$,

$$\tan v=\ (F/H)\,(3\cos^2\beta\sin^2\alpha-1) \tag{86}$$

This is an A-type of deflection at constant distance and differs from the A-type considered in section 19 by the presence of the factor $\cos^2\beta$. Tan v varies from $-F/H$ to $F/H\,(3\cos^2\beta-1)$ and becomes zero for a given value of β when

$$\sin^2\alpha=1/\,(3\cos^2\beta) \tag{87}$$

When $\phi=0$, $\tan v=3\,(F/H)\cos^2\beta\sin\alpha\cos\alpha$, which is a B-type of deflection at constant distance.

28. *Plane parallel to xy-plane, perpendicular type of deflections*—When the center of M_a moves in the parallel plane, along a line parallel to the x-axis, with its magnetic axis also perpendicular to x-axis, $\phi=90°$ and d is variable, we have the primary perpendicular-type represented by the equation

$$\tan v=(M_a/d^3H)\,(3\cos^2\beta\sin^2\alpha-1) \tag{88}$$

For D=shortest distance between centers of magnets we have the relations $D^2=b^2+c^2$, $d^2=a^2+b^2+c^2=D^2+a^2$, $\cos^2\beta=(a^2+b^2)/d^2$, $\sin^2\alpha=b^2/(a^2+b^2)$ and

$$\tan v=(M_a/H)\left\{[2D^2-(a^2+3c^2)]/(D^2+a^2)^{5/2}\right\} \quad \text{(primary perpendicular-type)} \tag{89}$$

For the secondary perpendicular-type, M_a moves along a line perpendicular to x-axis, and in line with it. The relations are then $D^2=(a^2+c^2)$, $d^2=(D^2+b^2)$, $\cos^2\beta=(a^2+b^2)/d^2$, $\cos^2\alpha=\ a^2/(a^2+b^2)$, and

$$\tan v=(M_a/H)\,[(2b^2-D^2)/(D^2+b^2)^{5/2}] \quad \text{(secondary perpendicular-type)} \tag{90}$$

29. *Plane parallel to xy-plane, parallel type of deflections*—In this case $\phi=0$, so that, from (83)

$$\tan v=(3M_a/d^3H)\ (\cos^2\beta\sin\alpha\cos\alpha) \tag{91}$$

Substituting the relations already given

$$\tan v=(3M_a/H)\ (ab/d^5) \tag{92}$$

30. *Constant deflections, xy-plane*—In section 15 we found the condition for zero-deflections. It is sometimes convenient for testing purposes to place the deflecting-magnet on a curve along which the deflections are constant. There are two cases to be considered, (*a*) when, except for the deflection, the magnets are perpendicular to each other, and (*b*) when the magnets are approximately parallel to each other. In the first case, $\phi=90°$, so that the desired expression is, from (22)

$$d^3=(M_a/H\tan v)\ (3\sin^2\alpha-1) \tag{93}$$

in which v is the given deflection. This is the polar equation of the curve sought. The curve is given in Figure 6 for $M_a=10{,}000$, $D=200$ cm, $H=0.1856$ c. g. s., and $v=46'\ 18''$. Beginning with angle of $\alpha=-35°$ approximately and traversing the circumference from x toward y the branches giving the distances are described in the order 1, 2, 3, and 4 as indicated. In the second case, the magnets are approximately parallel, so that $\phi=0$, and (22) becomes

$$d^3=(3M_a/H\tan v)\sin\alpha\cos\alpha \tag{94}$$

in which v, as in the first case, is the given deflection. The curve is shown in Figure 7 for $M_a=10{,}000$, $D=200$ cm, $H=0.1856$ c. g. s., and $v=34'\ 34''$, and the order in which the branches are described is indicated.

31. *Variometer with torsion*—Hitherto we have not considered the effect of torsion in the fiber, which, if not removed by suitable adjustment, will cause the suspended magnet M_s to deviate from the meridian. The mutual torque of the magnets is given by equation (14). The torque exerted by the horizontal intensity H, and the torsion in the filament is given by equation (12). For equilibrium, the sum of (12) and (14) is zero and

$$F[3\cos\beta\cos\delta\sin(\alpha-\theta)-\cos\omega\sin(\phi-\theta)]=H\sin\theta-(h/M_s)\ (\delta-\theta) \tag{95}$$

Expanding and collecting according to the factors $\sin\theta$ and $\cos\theta$,

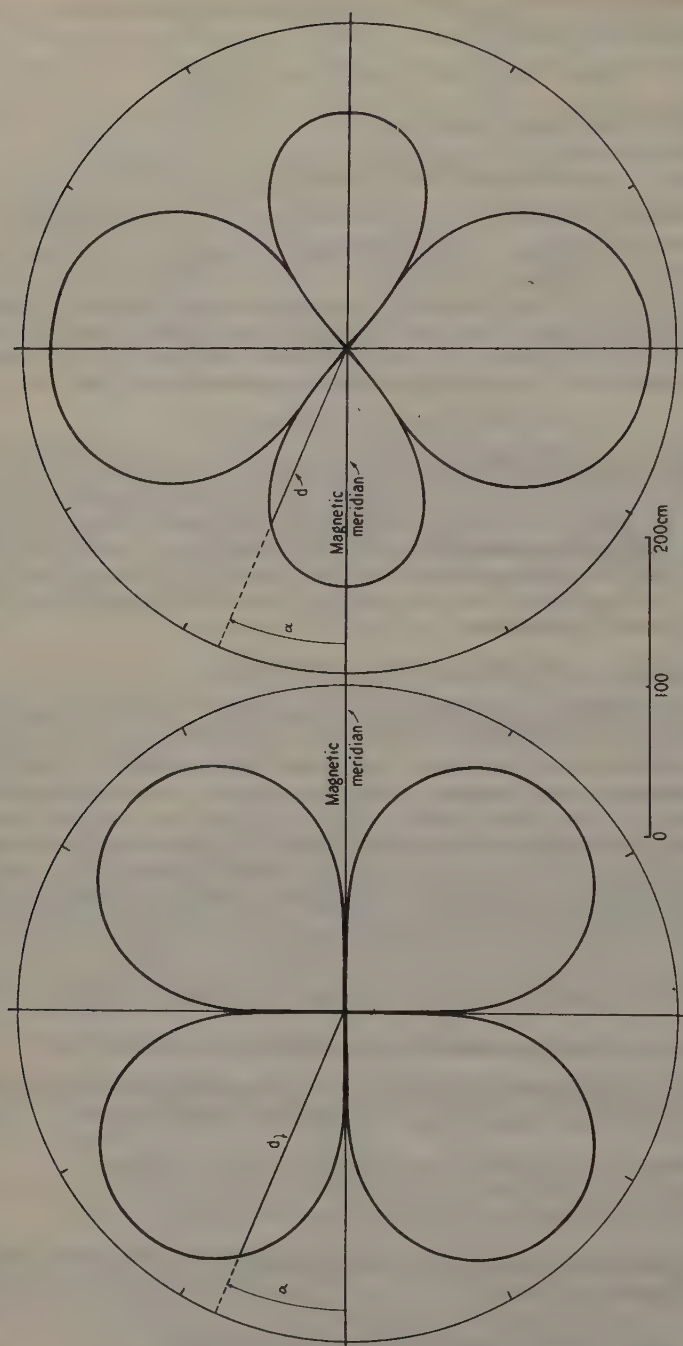
$$(F\cos\omega\cos\phi-3F\cos\delta\cos\beta\cos\alpha)\sin\theta+(3F\cos\delta\cos\beta\sin\alpha-F\cos\omega\sin\phi)\cos\theta=H\sin\theta-(h/M_s)\ (\delta-\theta) \tag{96}$$

Let the coefficient of $\sin\theta=E_1$, and that of $\cos\theta=E_2$, then

$$E_1\sin\theta+E_2\cos\theta=H\sin\theta-(h/M_s)\ (\delta-\theta) \tag{97}$$

Let θ_0 define the position of equilibrium of magnet M_s. The actual position will be (θ_0+v). Then

$$\left\{\begin{array}{l}\sin\theta=\sin(\theta_0+v)=\sin\theta_0\cos v+\cos\theta_0\sin v\\ \cos\theta=\cos(\theta_0+v)=\cos\theta_0\cos v-\sin\theta_0\sin v\end{array}\right\} \tag{98}$$



FIGS. 6 and 7—Constant deflections, xy-plane, for $M_a=10{,}000$, $d=200$ cm, $D=200$ cm, and $H=0.1856$ c. g. s. (6, magnets perpendicular to each other, $v=46' 18''$; 7, magnets approximately parallel to each other, $v=34' 34''$)

Substituting in (97), dividing through by cos v, noting that $[H \sin \theta_0 - (h/M_s \cos v)\ (\delta-\theta_0)]=0$ for equilibrium, and $v=\tan v$ for small angles

(99) $\tan v=(E_1 \sin \theta_0+E_2 \cos \theta_0)/(E_2 \sin \theta_0-E_1 \cos \theta_0+H \cos \theta_0+h/M_s \cos v$

Equation (99) is the general expression for the deflections of a suspended-magnet variometer.

32. *D-variometer with torsion*—When the filament is free from torsion, the magnet M_s will lie in the meridian. In this case, $\theta_0=0$, and (99) becomes

(100) $\tan v=E_2/(-E_1+H+h/M_s \cos v)=F\ (3 \cos \delta \cos \beta \sin \alpha-\cos \omega \sin \phi)/[-F\ (\cos \omega \cos \phi-3 \cos \delta \cos \beta \cos \alpha)+H+h/M_s \cos v]$

and neglecting the small quantities in the denominator

(101) $\tan v=F(3 \cos \delta \cos \beta \sin \alpha-\cos \omega \sin \phi)/(H+h/M_s)$

This is the same as equation (17) except for the term h/M_s, which represents the effect of torsion. The value of h/M_s is usually obtained from equation (12) from which, for small values of θ, $h/M_s=H\theta/(\delta-\theta)$, in which δ is a convenient angle through which the head has been turned. The denominator in (101) is then $H(1+f)$, in which f is the torsion-factor. Usually the D-variometer is for a convenient scale-value of 1′ per mm on the magnetogram, placed at the distance 1718.9 $(1+f)$ mm, so that the torsion is thus taken into account.

33. *H-variometer*—In the H-variometer, the position of equilibrium of the suspended magnet M_s is $\theta_0=90°$. From (99), v' referring to the H-variometer

$$\tan v'=E_1/(E_2+h/M_s)=F\ (\cos \omega \cos \phi-3 \cos \delta \cos \beta \cos \alpha)/[F\ (3 \cos \delta \cos \beta \sin \alpha-\cos \omega \sin \phi)+h/M_s]$$

and neglecting small quantities in the denominator

(102) $\tan v'=F\ (\cos \omega \cos \phi-3 \cos \delta \cos \beta \cos \alpha)/(h/M_s)$

We have the relations:

(103) $-\delta H/\delta\theta=h/M_s\doteq S=$ scale-value per radian (*HIV*, eq. 57)

(104) $s=S\epsilon\times10^5=$ scale-value per mm in gammas (*HIV*, p. 22)

(105) $v'=u'\epsilon$ (*HIV*, eq. 85)

Hence our equation for the H-variometer is

(106) $u'=F_\gamma\ (3 \cos \delta \cos \beta \cos \alpha-\cos \omega \cos \phi)/s$

in which $F_\gamma\equiv-M_s/d^3$ is the field-strength of the deflecting-magnet M_a in gammas.

34. *H-variometer, special cases*—When the center and the axis of M_a lie in the xy-plane, $\beta=\omega=0$, $\cos \delta=\cos (\alpha-\phi)$, and

(107) $u'=F_\gamma\ (3 \cos (\alpha-\phi) \cos \alpha-\cos \phi)/s$

Expanding and collecting terms

(108) $u'=(F_\gamma/s)\ [(3 \cos^2 \alpha-1) \cos \phi+3 \sin \alpha \cos \alpha \sin \phi]$

(109) When $\phi=0$, $u'=(F_\gamma/s)\ (3 \cos^2 \alpha-1)$ (*A*-type, constant distance)

(110) When $\phi=90°$, $u'=(3\ F_\gamma/s) \sin \alpha \cos \alpha$ (*B*-type, constant distance)

Thus we have characteristic curves similar to those of the D-variometer, $\sin \alpha$ being replaced by $\cos \alpha$, and H being replaced by s. The exchange

of sin α and cos α amounts simply to turning the axes of x and y through 90° in their own plane. Equation (109) will be zero when

$$3\cos^2\alpha - 1 = 0, \text{ that is, for } \alpha = 54°\ 44' \tag{111}$$

Equation (110) will be a maximum at constant distance when $\alpha=45°$. When $\phi=0$ and the center of M_a moves along a line perpendicular to the x-axis, at distance D, $d^2=D^2+b^2$, $\sin\alpha=b/d$, and $\cos\alpha=a/d=D/d$, so that (109) is then

$$u'=(M_a/s)\,[(2D^2-b^2)\times 10^5/(D^2+b^2)^{5/2}] \qquad \text{(primary perpendicular-type)} \tag{112}$$

This is the analog of equation (57) and has the same properties. When $\phi=0$, and the center moves along a line perpendicular to y-axis, $\sin\alpha=b/d$, $\cos\alpha=a/d$, $D=a$, $d^2=D^2+a^2$ and

$$u'=(M_a/s)\,[(2a^2-D^2)\times 10^5/(D^2+a^2)^{5/2}] \qquad \text{(secondary perpendicular-type)} \tag{113}$$

This is the analog of (63) and has the same properties. Under the same conditions (110) becomes

$$u'=(3M_a/s)\,[ab\times 10^5/a^2+b^2)^{5/2}] \qquad \text{(parallel type)} \tag{114}$$

$D\equiv a$ or $D\equiv b$ according as the magnet M_a moves along a line perpendicular to the x-axis, or parallel to the x-axis. This is the analog of (68)). Thus in the case of the H-variometer, there are the same types of deflections as in the case of the D-variometer. Their properties are the same, and hence no further discussion of them is necessary.

35. *Ex-meridian effect, D-variometer*—Dropping terms which are negligibly small or vanish in the denominator of equation (99)

$$\tan v=(E_1\sin\theta_0+E_2\cos\theta_0)/(H\cos\theta_0+h/M_s) \tag{115}$$

in which $E_1 = F\,(\cos\omega\cos\phi - 3\cos\delta\cos\beta\cos\alpha)$

$$E_2=F\,(3\cos\delta\cos\beta\sin\alpha-\cos\omega\sin\phi) \tag{116}$$

It will be sufficient to consider the xy-plane only. In this case, $\omega=\beta=0$, $\cos\delta=\cos(\alpha-\phi)$, whence

$$E_1=F[\cos\phi-3\cos(\alpha-\phi)\cos\alpha] \tag{117}$$

$$E_2=F[3\cos(\alpha-\phi)\sin\alpha-\sin\phi] \tag{118}$$

or

$$E_1=F[-3\sin\alpha\cos\alpha\sin\phi+(1-3\cos^2\alpha)\cos\phi] \tag{119}$$

$$E_2=F[(3\sin^2\alpha-1)\sin\phi+3\sin\alpha\cos\alpha\cos\phi)] \tag{120}$$

Then for the deflections

$$\tan v=(F/H\cos\theta_0+h/M_s)[(-3\sin\alpha\cos\alpha\sin\phi+(1-3\cos^2\alpha)\cos\phi]\sin\theta_0+(F/H\cos\theta_0+h/M_s)[(3\sin^2\alpha-1)\sin\phi+3\sin\alpha\cos\alpha\cos\phi]\cos\theta_0 \tag{121}$$

An important special case arises when the magnet M_a rotates with the deflection-bar, and in line with it, or, what is the same thing, rotates at constant distance with its axis always pointing to the center of the suspended magnet M_s. Then $\alpha=\phi$, $E_1=-2F\cos\alpha$, $E_2=2F\sin\alpha$, and

$$\tan v=[2F/(H\sin\theta_0+h/M_s)]\sin(\alpha-\theta_0) \tag{122}$$

36. *Ex-meridian effects, deflection-curves, D-variometer*—Transforming equation (121) into ordinates by means of the rotations

(123) $$S=(h/M_s)\,\epsilon_D\times10^5$$

(124) $$v=-u\epsilon_D$$

in which ϵ_D is the value in radian of one mm on the magnetogram for the D-variometer.

(125) $$u=[F_\gamma/H_\gamma\,\epsilon_D\sin\theta_0+S)]\,[3\sin\alpha\cos\alpha\sin\phi+(3\cos^2\alpha-1)\cos\phi]\sin\theta_0 +[F_\gamma/(H_\gamma\,\epsilon_D\cos\theta_0+S)][(1-3\sin^2\alpha)\sin\phi+3\sin\alpha\cos\alpha\cos\phi]\cos\theta_0$$

If M_a is parallel to the x-axis, $\phi=0$, so that (125) becomes

(126) $$u=F_\gamma[(3\cos^2\alpha-1)\sin\theta_0+3\sin\alpha\cos\alpha\cos\theta_0]/(H_\gamma\epsilon_D\cos\theta_0+S)$$

When $\phi=90°$,

(127) $$u=F_\gamma[3\sin\alpha\cos\alpha\sin\theta_0+(1-3\sin^2\alpha)\cos\theta_0]/(H_\gamma\epsilon_D\cos\theta_0+S)$$

The deflection-equation for D-variometer in ordinates is obtained from (125) by placing $\theta_0=0$,

(128) $$u=F_\gamma[(1-3\sin^2\alpha)\sin\phi+3\sin\alpha\cos\alpha\cos\phi]/(H_\gamma\epsilon_D+S)$$

When $\phi=0$

(129) $$u=F_\gamma\,(3\sin\alpha\cos\alpha)/(H_\gamma\epsilon_D+S)$$

When $\phi=90°$

(130) $$u=F_\gamma\,(1-3\sin^2\alpha)/(H_\gamma\epsilon_D+S)$$

The deflection-equation in ordinates for an H-variometer is obtained from (125) by placing $\theta_0=90°$

(131) $$u'=(F_\gamma/S)[(3\sin\alpha\cos\alpha\sin\phi+(3\cos^2\alpha-1)\cos\phi]$$

When $\phi=0$

(132) $$u'=(F_\gamma/S)\,(3\cos^2\alpha-1)$$

When $\phi=90°$

(133) $$u'=(3F_\gamma/S)\sin\alpha\cos\alpha$$

Comparing (126), (129), and (132) we see that when $\phi=0$ the actual deflections are compounded of a deflection-curve (132) appropriate to an H-variometer, and a curve (129) appropriate to a D-variometer. Likewise, when $\phi=90°$, (127) is compounded of a curve (130) belonging to a D-variometer, and a curve (133) belonging to an H-variometer. In other words, the variometer performs as D-variometer having the component $M_s\cos\theta$, in the magnetic meridian, and at the same time as an H-variometer having the component $M_s\sin\theta_0$ perpendicular to the meridian. Hence, in adjusting D- and H-variometers, care must be taken to orient the magnet of the D-variometer exactly in the magnetic meridian, or to orient the magnet of the H-variometer exactly in the magnetic prime-vertical, otherwise the record will be a combination of both declination and horizontal-intensity variations.

37. *Conditions for vanishing of mutual torque*—The mutual torque is given by equation (14), which is zero when $\alpha=\theta=\phi$, that is, when the axes of the magnets are in the same vertical plane. The angle ω may have any value, so that the mutual torque vanishes whatever may be the inclination of the axes of the magnets in this vertical plane. The mutual torque is also zero when $\phi=\theta$ (magnets parallel) and $(\alpha-\theta)=90°$ (magnets perpendicular to line d), provided further $\omega=0$ (magnet level) or $\beta=0$ (center in xy-plane), or both $\omega=0$ and $\beta=0$.

We are more particularly concerned with the xy-plane, so that $\beta=\omega=0$. We then have from (4) and (14)

$$(134) \qquad -(\delta V/\delta\theta)=FM_s\,[3\cos(\alpha-\phi)\sin(\alpha-\theta)-\sin(\phi-\theta)]$$

This is zero when $\alpha=\phi=\theta$, that is, when the magnets are in the same straight line. Equation (134) is also zero when $\phi=\theta$, and $(\alpha-\phi)=90°$, that is, when the magnets are parallel and at the same time perpendicular to the line d, joining their centers. The first condition is more convenient in application. The physical significance is that each magnet lies along a line of force proceeding from the other.

38. *To determine the pointing of the suspended magnet*—By rotating the deflection-bar to which the deflecting-magnet M_a is attached, with its axis in line with the bar, a position will be found such that $\alpha=\theta_0$, so that $\tan v$ in (122) is zero. From what has been stated in the preceding section, since M_a exerts no torque on the suspended magnet, both magnets are therefore in the same straight line, that is, the pointing of M_a indicates the pointing of M_s. Some observational details may be necessary. For example, if M_a is not in line with the bar, it would be necessary to reverse M_a and take the mean deflection.

Without a bar, some other scheme may be used, whereby the center of M_a moves in a circle, with its axis always pointing to the center of the variometer. Thus, if the position of the bar when in the meridian is known, the angle θ_0 will indicate the angular deviation of the suspended magnet from the meridian. Moreover, if we make deflections, or double deflections (by reversing M_a) at an angle θ_0 each side of the meridian, we shall have $\tan v=[2F/(H\cos\theta_0+h/M_s)]\sin\theta_0=0$, in one case, and $\tan v=[2F/(H\cos\theta_0+h/M_s)]\sin(-2\theta_0)$ in the other. Or in general, the deflections will be unequal if made at angles of about θ_0 in magnitude each side of the meridian. After turning the torsion-head as indicated by the experiment, the process may be repeated until symmetrical deflections are obtained; the suspended magnet will now be in the meridian. The same result may be reached by turning the torsion-head until no deflection is produced when the deflecting-magnet is placed on or removed from the bar, which has been oriented in the meridian. If the position of the meridian is unknown, the variometer-magnet may be placed in the meridian by adjusting the torsion-head until equal turns in opposite directions produce equal deviations. The bar with deflecting-magnet in place may be oriented in the meridian by the procedure described above, thus affording a convenient determination of the magnetic meridian. When the prime-vertical is known, the bar-method above described may be used for adjusting the magnet of the H-variometer in the magnetic prime-vertical.

(*To be continued*)

AURORAL OBSERVATIONS AT THE ALASKA AGRICULTURAL COLLEGE AND SCHOOL OF MINES, 1930-31[1]

By Veryl Fuller

Description of stations—The two points of observation used for the auroral work are located a little over fourteen miles apart. One, designated as Station 1, is on the college campus: The other, Station 2, is on the Richardson Highway in a southeasterly direction from Station 1. The choice of an outlying station is limited as transportation must be reasonably easy. There are only two possible directions in which the outlying station can be situated. A northerly one and the one chosen. Aside from the direction Station 2 is well located. It has a clear view in all directions. It is easily accessible except in the most severe weather

[1]This is a summary of a more extended report submitted on the results obtained during the season 1930-31 at the auroral station, Alaska Agricultural College and School of Mines, at College, Alaska. This station was made possible following the recommendation of the American Geophysical Union, the United States Coast and Geodetic Survey, and the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, by the generosity of the Rockefeller Foundation, whose Executive Committee passed on November 8, 1929, a resolution appropriating to the College the sum of $10,000 to establish, equip, and maintain a first-order auroral station at College near Fairbanks, Alaska, to carry out a five-year program of research on the aurora. The site chosen is particularly favorable for this purpose. In addition to physical and cultural considerations, it has an unique advantage as regards geographical position, being practically 180° distant in longitude from the first-order auroral station in Norway, the existence of which was likewise made possible through the generosity of the Rockefeller International Education Board.

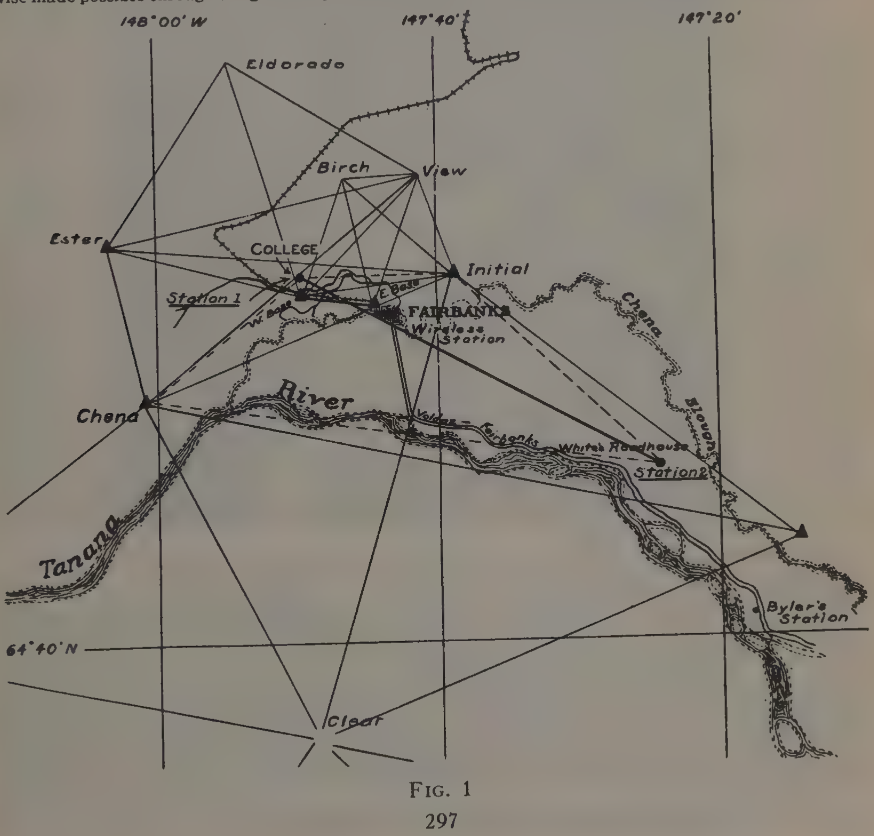


FIG. 1

and is at a distance which has proven to be sufficient for most types of auroras.

The distance between the two stations was determined quite accurately by triangulation, using data and base-lines established previously, by the United States Coast and Geodetic Survey and the Land Office. Because of poor weather conditions it was necessary to turn the angles at night using gasoline lanterns as targets. This work was done by Professor R. W. Chase of the Civil Engineering Department of the College. The results of this work give the following data:

Station No. 1—Latitude, 64° 51′ 26″.83; longitude, 147° 49′ 19″.62; azimuth to Station No. 2, 296° 28′ 54″.2; distance to Station 2, 22822.2 meters.

Station No. 2—Latitude, 64° 45′ 56″.00; longitude, 147° 23′ 34″.36; azimuth to Station No. 1, 116° 52′ 12″.5.

Figure 1 shows the location of the two stations and the system of lines used in the triangulation for the distance between the two stations.

Photographic equipment—The photographic equipment used here consists of two special cameras constructed by Karl Ormestad in Oslo, Norway, according to a design originating with Professor Carl Störmer[2]. They are so constructed that six pictures may be taken on one plate in rapid succession by a simple movement of the lens. Adjustment for vertical swing is accomplished by mounting the camera on a gimbal. Thumb-nuts hold the camera in any vertical position. The horizontal adjustment consists of a swivel in the tripod-head. The shutter is a rectangular metal cover hinged to the camera-frame and is of the right size to cover the lens in each of its six positions. This is operated by a small crank at the top of the instrument. The lens is a Hugo Meyer Kino Plasmat having an aperture ratio of f:1.5 and a focal length of 50 mm. The camera is mounted on a sturdy tripod when in use. Each camera is equipped with twelve 9 by 12 cm single, metal plate-holders, carrying-case, ground-glass, lens cleaner, and dark cloth.

Some minor additions and alterations were made in order to make the instruments easier to use with the scheme of ob ervation employed here. The view-finders with which the cameras were originally equipped were not suited to them since they did not show the same size of field of view as the size of picture taken and were besides difficult to use at night. These were replaced by a simple box-type finder which has proven much more usable. The finder consists of a small sheet-metal box open at the front except for vertical and horizontal cross-wires to indicate the center of view. At the back is a small peep-hole. The size of the opening and the length of the box is so proportioned that the field of view is the same as that of the camera lens.

Horizontal circles divided in degrees were put on the gimbal-frame for the purpose of approximate orientation in a horizontal circle. By establishing a true north-and-south line at each station it is easy by the use of these circles to set the cameras at the two stations so that the optical axis of each has the same azimuth.

Vertical circles with levels were also put on the cameras in order that the approximate elevation of the optical axis could be determined. This circle with its level also serves to set the cameras for the purpose of taking the series of star pictures for constructing the "network" charts used in

[2]Apparatus for auroral photography, manuscript not yet published. For description of apparatus used on earlier expeditions see Geofys. Pub., 1, Nos. 1 and 5 (1921).

measuring parallax. Since the cameras are not intended to be leveled accurately when used for taking auroral pictures no leveling device was incorporated in them and for this reason the level used with the vertical circle is arranged so that it has a vertical motion about the center of vertical rotation of the camera.

Figure 2 shows clearly the construction of the camera and also the view-finder on the upper left corner, the horizontal circle, and the vertical circle with its level.

Communication—Although the two points of observation are located

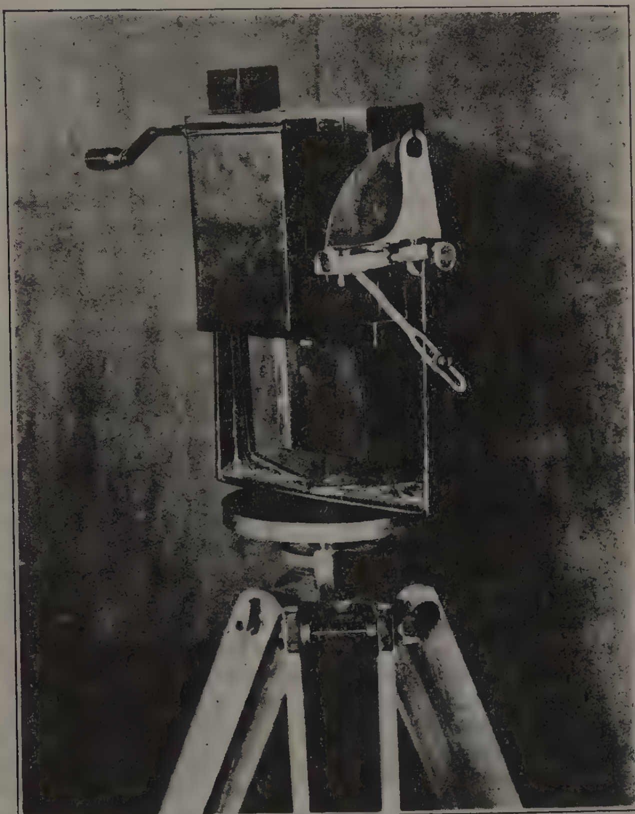


FIG. 2

on the highway near which a telephone line runs it was impossible to use telephones for inter-communication between the stations without constructing a new line because of the interference with regular communication during times of observation. This would have been quite expensive; for this reason therefore it was decided to use radio. Radio has the added advantage that should it be decided to extend the base-line or change it, there would be no difficulty in doing so without added expense.

Since most of the transmitting would be done at Station No. 1, the

transmitter installed there was one of the lowest possible power which would give assured continuous contact with the outlying station at all times. As the distance was only about fifteen miles a 7.5-watt set was selected as having sufficient power to cover this distance even under the worst conditions. Accordingly a set was constructed designed to work in the 80-meter amateur band and capable of transmitting either code or voice. This set consisted of a Hartley oscillating circuit coupled inductively to the antenna and modulated by the constant-current method. The type 210 oscillator-tube is fed by a type 250 modulator which in turn is fed by one stage of transformer-coupled audio amplification using a type 12 tube.

The transmitter receives its power from a R. E. L. catalogue No. 185 power-pack. This is supplied with 110-volt alternating-current power from a motor-generator set since only 110-volt direct-current is available at the college. It seemed more practical to use the motor-generator and power-pack than to install a high-voltage motor-generator set, for an alternating-current motor-generator was already installed in my home where the set would be used; further if found advisable at a future time to use a more powerful set it would only be necessary to replace the power-pack.

The receiver at this station is a Silver-Marshal four-tube set operated from the conventional "A" and "B" batteries.

The antenna system consists of two complete antennas each with a counterpoise. For transmitting, a quarter-wave system is used. For receiving, a short antenna is used, and because of the poor ground which frozen earth makes, it was found necessary to use a counterpoise for receiving as well as sending.

The equipment is installed in the author's home on the campus and is operated by the person taking notes who is in constant communication with the observer at the camera by means of a telephone. When voice is used the observer's telephone is connected by a switching arrangement to both the person taking notes and the radio transmitter so that the observer is in direct communication with the outlying station and at the same time with the person taking notes.

The radio apparatus to be used at Station No. 2 had to be easily portable and at the same time reliable. For the latter reason a circuit was chosen for the transmitter using the same type of tubes used in the receiver. All tubes in both the transmitter and receiver are of the −01A type. This arrangement was used so that replacement would be simplified in case of accident to tubes and necessitated the carrying of only one or two extra tubes which could be used in any socket of either receiver or transmitter.

Both the transmitter and receiver were built according to designs given in Engineering Circular No. 10 of the Burgess Battery Company and are similar to those used by the Wilkins-Detroit Arctic Exposition.

The transmitter uses the series Colpitts circuit employing two −01A tubes in parallel. The transmitter has proven to be stable in operation and very dependable.

The receiver is the ordinary three-tube regenerative detector-circuit using capacity-coupling to the antenna and needs no description.

The transmitter and receiver are both mounted in a light yet substantial plywood case, provided with a strip for carrying.

The same antenna and counterpoise are used for both receiving and sending as are also the "A" and "B" batteries. A push-button operated change-over switch, which is conveniently located for the operator, makes this possible.

Time was kept by a Waltham watch and checked against standard time-signals as often as possible, on an average of three times a week. Its rate was found to be fairly constant and had a mean of 0.093 second per hour. A pendulum-clock was available but its rate was unreliable and it was located in an inconvenient place for observational purposes.

"Network" charts—In order to measure the parallax shown by the auroral negatives, charts of the same size as the enlarged negatives are necessary. These consist of right-ascension and declination circles having the distortion due to the camera lens and the projector lens introduced in their construction. By having a large number of these charts representing different parts of the sky along the meridian it is possible to measure the parallax directly with a minimum of preliminary calculation.

The method of preparing these charts, which is due to Professor Harang of Tromsö, Norway, is as follows:

The aurora camera is set up with its optical axis in the plane of the above mentioned meridian. Six or more exposures are then made with a time-interval of eight minutes (star-time) between each exposure. The length of the exposure is just long enough to get an image of the stars without showing any appreciable motion. When the six or eight exposures are made the lens is shifted to a new plate and the camera is elevated to a new position about a degree or two higher than the first and the process of exposure repeated. This is done for all positions from the horizon to well beyond the zenith. The resulting negatives each show a series of pictures of the same group of stars spaced exactly two degrees apart, since the motion of the celestial sphere is one degree in four minutes of time.

To construct the "network" charts then one puts the negative in the projector used for the auroral pictures and adjusts the amount of enlargement until, near the center of the plate one degree (along the meridian) exactly equals one centimeter. This is done by identifying two stars near the center of the plate and computing the difference in degrees between their respective declinations. To check this the cosine of the declination of one of the stars just used is found and when multiplied by two should give the distance in centimeters between the successive images of the star.

When the correct enlargement has been obtained each star-image is plotted on a piece of paper and also the center of the plate. A meridian is then located by calculating the distance in right-ascension from the center of the plate for stars having different declination. After the meridian through the center is located, it is an easy matter to draw in the circles of declination and of hour-angles by simply plotting the correct distance as indicated by the star-images. When the lines have all been plotted a tracing is made in ink, the center is marked with the correct declination of the point, and the chart is ready to use. The whole process is a simple one but requires much time and proves rather tedious when a large number of the charts is required, because extreme care must be exercised in plotting the points and often the star-images are faint which

adds to the difficulty. However, the making of them by this method, long as it is, saves much time over the method of calculating the "network" from the empirical equation for the distortion of the camera lens and projector lens.

So far only fifteen of these charts have been made; however, these are made for use in the part of the sky where most of the aurora photographs which are good can be calculated.

Visual record of aurora.—It is not always possible to send observers to Station No. 2 in time to obtain observations before the display has ended and sometimes the display is so weak that it is inadvisable to make an attempt to make photographic observations. It is, therefore, with this in mind that a record is kept of all displays observed. This record is kept in tabular form that the data may serve to correlate other natural pheomena with the aurora or to determine frequency- or time-curves.

The record includes the following data as shown by the column headings of Table 1.

(1) The date of the G. M. T. given; since midnight G. M. T. is 2 P. M. local standard time this column shows a date one day ahead of the local date. (This is convenient for one date, therefore, can be used during the entire display and makes also a standard of reference.)

(2) The G. M. T. of the first observation of a display.

(3) The form of aurora according to designations of the Photographic Atlas of Auroral Forms[3], as follows: (1) Forms without ray-structure—*HA*, homogeneous quiet arcs, *HB*, homogeneous bands, *PA*, pulsating arcs, *DS*, diffuse luminous surfaces, *PS*, pulsating surfaces, and *G*, feeble glow near the horizon resembling the dawn, of white or reddish color; (2) forms with ray-structure—*RA*, arcs with ray-structure, *RB*, bands with ray-structure, *D*, draperies, *R*, rays, and C, corona; and (3) flaming aurora, *F*.

(4) Intensity measured by using different thicknesses of celluloid as a measure—28 thicknesses just obscure the full moon.

(5) Altitudes for the lower and upper border at the center of the display—*Z* indicating zenith and *H* horizon.

(6) The western and eastern extremities of the display.

(7) The duration in hours between the first and final appearance of the aurora.

(8) The approximate area of the sky covered as a maximum on a scale of 1 to 8 (8 being the entire sky).

(9) Weather condition at the time of observation, including cloudiness, rain, snow, and wind.

(10) Height of barometer at time of observation, indicating by *r* or *f* whether it is rising or falling.

(11) Any additional notes which need to be entered.

(12) Number of photographic exposures made if any.

[3]C. Störmer, Photographic atlas of auroral forms and scheme for visual observations of auroræ. Published by International Geodetic and Geophysical Union, Oslo (1930).

TABLE 1—*Auroral record, College, Alaska, August 9, 1930, to May 7, 1931*

Date	G.M.T.	Form	Intensity	Altitude Lower	Altitude Upper	Extension West	Extension East	Duration	Max. area	Weather	Barometer	No. exp.	Remarks
1930	h m			°	°			h					
Aug. 9	09 00	*R*	2	20	65	....	N 45 E	0.5	1	Cloudy	29.2*f*	..	A single ray changing in intensity but stationary
10	08 30	*R*	5	15	65	....	N 45 E	0.2	1	Cloudy	29.1*r*	..	Single ray visible only short time; rain
14	12 30	*R*	2	35	60	....	N 45 E	0.2	1	Cloudy	29.3*f*	..	Single ray
15	11 00	*R*	4	20	70	....	N 60 E	0.2	1	Cloudy	29.1*f*	..	Single ray showing some motion and color; rain
21	09 30	*HA*	3	20	30	N 20 W	E	0.3	3	V. cloudy	29.3*r*	..	Arc seen intermittently through clouds; rain
22	09 30	*HA*	3	25	30	N 20 W	N 60 E	0.2	2	Cloudy	29.4*r*	..	Rain
24	11 30	*HA*	3	20	25	N 20 W	N 60 E	0.5	3	Cloudy	29.2*r*	..	Seen intermittently through clouds; rain
25	08 30	*HA*	4	25	30	N 45 W	N 30 E	0.5	3	Cloudy	29.3	..	
26	07 00	*G*	2	10	45	N 20 E	N 50 E	5	1	Pt. cloudy	29.4*r*	..	
27	10 20	*HA*	5	25	30	N	E	0.2	2	Cloudy	29.5*r*	..	Single arc; rain
29	11 20	*HA*	8	20	30	N 30 W	E	0.4	2	Cloudy	29.4*r*	..	Rain
30	10 00	*DS*	5	....	....	....	N 45 E	0.3	1	Pt. cloudy	29.6*f*	..	
Sep. 1	06 00	*HA*	3	15	20	N 45 E	N	3	4	Cloudy	29.3	..	Died out at 07ʰ 00ᵐ; came out as *G* changed to *HA* at 08ʰ 30ᵐ
3	07 00	*DS*	5	....	....	....	NE	0.2	1	Cloudy	29.3*f*	..	Diffuse glow in NE
4	08 00	*RB*	12	30	45	N 45 W	E	5	6	Pt. cloudy	29.2*f*	..	Very brilliant; showing color; moving; changing form
6	07 00	*RB*	7	30	$Z+20$	N 45 W	E 20 S	1	6	Pt. cloudy	29.4*f*	..	Moving rapidly; showing color
7	10 00	*RB*	5	25	80	N	E	0.5	5	Pt. cloudy	29.2*f*	..	
8	09 30	*G*	2	....	....	....	N 30 E	0.3	.	Cloudy	29.2*r*	..	
9	12 00	*HA*	4	15	20	N	N 45 E	0.5	2	Clear	29.4	..	
15	10 00	*HA*	6	15	20	N 20 W	E	2	3	Pt. cloudy	29. *r*	..	Changed to *RA* at 10ʰ 50ᵐ; back to *HA* at 11ʰ 00ᵐ

TABLE 1—*Auroral record, College, Alaska, August 9, 1930, to May 7, 1931*—Continued

Date	G.M.T.	Form	Intensity	Altitude Lower	Altitude Upper	Extension West	Extension East	Duration	Max. area	Weather	Barometer	No. exp.	Remarks
1930	h m			°	°			h					
Sep. 16	07 30	*DS*	3	20	*Z*	N 45 E	E	2	2	Clear	29. *r*	..	
17	08 00	*DS*	2	Near *H*	Near *H*	....	N 45 E	2	1	V. cloudy	29.1*r*	..	
18	08 30	*HA*	5	25	28	N 30 W	E	0.5	3	Pt. cloudy	29.2*r*	..	
19	07 00	*DS*	2	25	40	....	N 20 E	5	4	Cloudy	28.9*f*	..	
21	07 15	*HB*	10	....	*Z*	N 15 W	E 20 S	0.5	2	Pt. cloudy	29.4*r*	..	Brilliant; showing color
22	06 00	*HA*	7	20	25	N 30 W	E	7	2	Pt. cloudy	29.4*f*	..	
23	08 45	*HA*	5	25	30	N 20 W	E	4	4	Clear	29.4*f*	..	
24	12 00	*HA*	3	15	18	N	E	2	2	Cloudy	29.2*f*	..	
27	10 00	*HA*	5	20	25	N	E	1.5	2	Clear	29.0*f*	..	
28	06 00	*HA*	6	15	35	N 45 W	E	2	3	Cloudy	28.7*f*	..	Series of arcs
30	05 30	*HB*	5	10	*Z*	N	N 45 E	0.5	3	Pt. cloudy	28.7	..	
Oct. 1	08 00	*HA*	4	15	20	N	E	0.5	2	Cloudy	29. *r*	..	
2	09 15	*HA*	2	20	25	N	E	3	2	Pt. cloudy	29.4	..	
3	05 00	*HA*	4	15	20	N 10 W	E	7	2	Cloudy	29.4	..	
4	05 00	*HA*	3	15	20	N 20 W	N 60 E	8	3	Clear	29.2*r*	..	
5	05 00	*HA*	4	20	30	N 10 W	E	5	2	Pt. cloudy	29.3*r*	..	
14	05 00	*HA*	2	75	150	N 45 W	E	7	6	Clear	29.9*f*	..	Lasted until after $12^{h}\ 00^{m}$
16	08 20	*HA*	4	10	15	N	N 45 E	5	3	Clear	29.7*r*	..	
17	07 15	*HA*	6	15	20	N 30 W	E	4	2	Clear	29.7	..	
18	09 40	*HA*	5	20	25	N 20 W	E	5	3	Clear	29.7*f*	..	
19	06 30	*DS*	3	30	35	N 30 W	N 45 E	5.5	2	Clear	29.1	..	At $08^{h}\ 00^{m}$ began to fade; at $09^{h}\ 00^{m}$ changed to *HA*
20	10 00	*HR*	5	15	20	N	N 60 E	1	2	Pt. cloudy	29. *f*	..	
21	05 00	*HA*	5	15	20	N	N 70 E	3	2	Clear	29.1	..	Single arc changed to *G* in NE at $05^{h}\ 30^{m}$
22	08 00	*DS*	3	Near *H*	Near *H*	N	NE	5	1	Pt. cloudy	29. *r*	..	
23	11 00	*RB*	4	20	50	N 20 E	N 60 E	4	3	Pt. cloudy	29.1*f*	..	
24	08 30	*RB*	3	15	50	N 20 E	N 45 E	1	3	Pt. cloudy	28.8*f*	..	
25	08 30	*HA*	3	20	30	N	NE	2	2	Pt. cloudy	28.6	..	
26	15 00	*C*	5	30	*Z*	N hemi.	N hemi.	2	5	Pt. cloudy	28.6*r*	..	Changed to *HA* at $15^{h}\ 30^{m}$

TABLE 1—*Auroral record, College, Alaska, August 9, 1930, to May 7, 1931*—Continued

Date	G.M.T.	Form	Intensity	Altitude Lower	Altitude Upper	Extension West	Extension East	Duration	Max. area	Weather	Barometer	No. exp.	Remarks
1930	h m			°	°			h					
Nov. 4	08 10	*G*	2	*H*	*H*	N	NE	3.5	1	Pt. cloudy	28.9	..	Very cloudy near horizon
14	05 20	*HA*	3	25	30	N 20 W	N 80 E	5	2	Cloudy	28.7*f*	..	Cloudy near horizon; hazy overhead; snow falling
17	08 30	*HA*	3	Near *Z*	Near *Z*	....	....	3.5	1	Cloudy	29. *r*	..	
18	04 00	*HA*	3	15	20	N	E	8	4	Clear	29.1*f*	2	Very brilliant at 06h 30m; sky overcast by 13h 00m; see photo notes
20	05 30	*DS*	2	10	20	N	E	2.5	3	Cloudy	28.6*r*	..	
23	09 30	*R*	5	20	50	....	NE	0.5	3	Pt. cloudy	29.9*f*	..	
25	03 30	*HA*	3	15	20	NW	E	6.5	2	Pt. cloudy	30. *r*	5	See photo notes
26	07 30	*DS*	2	10	25	N	E	2	2	Clear	29.7*f*	..	
27	06 00	*HA*	1	15	20	N 30 W	E	2	3	Clear	29.3	4	See photo notes
28	06 00	*HA*	5	15	20	N 30 W	E	7	4	Clear	29.5*r*	..	
29	06 30	*HA*	5	20	25	N 45 W	E	3	3	Clear	29.6	..	
30	07 30	*HA*	3	20	25	N	E	2	2	Cloudy	28.8*r*	..	
Dec. 3	08 30	*G*	2	Low N	Low N	....	....	0.5	2	Pt. cloudy	28.9*f*	3	See photo notes
4	02 25	*HA*	5	10	15	N	E	15	2	Pt. cloudy	28.3*r*	..	
11	07 30	*HA*	3	20	25	N 20 W	E	2	2	Clear	29.1*f*	..	Much frost in air
14	08 30	*HA*	3	20	25	N	N 75 E	1	2	Pt. cloudy	28.7*r*	..	
17	06 00	*HA*	3	Near *H*	Near *H*	N	NE	13	1	Pt. cloudy	28.8	..	
18	06 00	*HA*	3	Near *H*	Near *H*	N	NE	3	1	Clear	28.8*r*	..	Changed to *DG* at 08h 00m
19	06 30	*HA*	2	Near *H*	Near *H*	N	NE	5	3	Clear	28.9	..	
20	07 20	*HA*	2	10	15	N	NE	12	1	Pt. cloudy	28.9	..	
21	06 00	*HA*	2	10	15	N	NE	9	4	Clear	28.8*r*	6	Corona at 08h 30m; see photo notes
22	06 30	*HA*	3	10	15	N	N	4	3	Pt. cloudy	28.8*f*	..	Rather diffuse
25	09 20	*HA*	5	30	35	N 20 W	E	6	3	Clear	28.6*f*	..	
26	06 00	*RA*	5	30	50	N	NE	9	4	Pt. cloudy	28.6*r*	..	
27	10 00	*RA*	5	20	30	N	E	1	4	Fog	28.7*r*	..	Changed to *DS* at 09h 30m; rays at 09h 40m; came and went until 17h 00m; see photo notes
29	09 10	*HA*	3	10	20	N 30 W	E	10	2	Cloudy	28.9*r*	..	

TABLE 1—*Auroral record, College, Alaska, August 9, 1930, to May 7, 1931*—Continued

Date	G.M.T.	Form	Intensity	Altitude Lower	Altitude Upper	Extension West	Extension East	Duration	Max. area	Weather	Barometer	No. exp.	Remarks
1931	*h* *m*			°	°			*h*					
Jan. 9	05 10	*DS*	2	8	20	N	N 70 E	6	2	Pt. cloudy	28.5*r*	11	See photo notes
10	02 30	*G*	2	10	40	N	NE	10	3	Pt. cloudy	28.7*r*	..	
12	10 30	*G*	3	Low	Low	N	....	5	3	V. cloudy	28.7*f*	..	Seen through clouds
13	09 45	*HA*	2	Near *H*	Near *H*	....	....	4	1	Clear	28.8*r*	..	Seen first as *G* near *H*; rose rapidly to form *HA* show-color
14	08 20	*HA*	5	10	15	N	E	3	3	Clear	28.7*f*	1	See photo notes
15	07 30	*G*	2	Near *H*	Near *H*	....	....	7	4	Pt. cloudy	28.6*r*	..	*G*, 07^h 30^m to 08^h 00^m; *HA*, 12^h 00^m to 12^h 40^m; intense arc at 16^h 30^m to 16^h 40^m
16	09 00	*HA*	3	15	20	NW	E	11	3	Pt. cloudy	29.1*r*	..	Cloudy until 11^h 30^m; *HA* at 12^h 00^m to 18^h 30^m
18	05 20	*G*	2	*H*	*H*	NE	....	1	2	Pt. cloudy	29.4	2	See photo notes
22	06 00	*HA*	5	10	12	NW	E	3	3	Clear	29.4*f*	3	See photo notes
24	08 15	*HA*	5	10	15	N	E	3	2	Pt. cloudy	28.8*r*	..	See photo notes
25	08 30	*HA*	1	10	12	N	E	4	1	Pt. cloudy	29. *r*	..	At 11^h 00^m faint *G* in N
26	06 30	*HA*	2	35	40	N 45 W	E	6	1	Clear	29.1	..	At 12^h 15^m bright drapes
27	08 30	*HA*	5	25	30	N 30 W	E	5	4	Pt. cloudy	28.9	4	See photo notes
28	07 00	*HA*	3	60	65	N	E	8	6	Pt. cloudy	29. *f*	12	See photo notes
29	11 30	*D*	7	20	80	N 45 W	N 80 E	1	3	Cloudy	28.5	..	Showing color; moving rapidly
31	09 00	*HA*	5	25	30	N	E	1	3	Pt. cloudy	28.8	..	Changed to *DS* at 09^h 30^m
Feb. 2	09 15	*PA*	8	*H*	*Z*	N 30 W	E	2	6	Pt. cloudy	29. *f*	..	Seen through clouds
4	07 00	*G*	2	Near *H*	Near *H*	....	NE	2	1	Pt. cloudy	29.3*f*	..	
6	11 30	*G*	Faint	Near *H*	Near *H*	....	NE	1	1	Cloudy	29.	..	
7	07 00	*HB*	3	25	30	N 20 W	N 60 E	2	3	Pt. cloudy	29.1*r*	..	Appeared intermittently
8	10 45	*DS*	3	30	*Z*	NW	....	1	4	Pt. cloudy	28.9	..	
9	07 45	*HA*	5	10	16	N 30 W	N 45 E	9	4	Clear	28.9	5	See photo notes
10	05 45	*HB*	3	15	20	N 45 W	E	9	2	Clear	28.8*f*	2	See photo notes
13	06 40	*G*	3	25	60	....	NE	4	3	Cloudy	28.7*r*	..	Changed to *HA* at 09^h 00^m
14	08 30	*HA*	4	15	20	N	E	2	2	Pt. cloudy	29. *f*	..	Seen intermittently through clouds

TABLE 1—*Auroral record, College, Alaska, August 9, 1930, to May 7, 1931*—Continued

Date	G.M.T.		Form	Intensity	Altitude		Extension		Duration	Max. area	Weather	Barometer	No. exp.	Remarks
					Lower	Upper	West	East						
1931	*h*	*m*			°	°			*h*					
Feb. 15	03	00	*HA*	4	20	22	N 45 W	E	12	5	Pt. cloudy	28.7*f*	10	See photo notes
16	07	20	*HA*	5	15	20	N 30 W	E	8	5	Pt. cloudy	28.7*r*	10	See photo notes
17	06	00	*HB*	5	15	20	N 45 W	E	9	2	Cloudy	29.	..	
21	07	30	*HB*	10	20	25	N 20 W	E	4	3	Clear	28.7	..	Changed to *D* and *R* at $08^h 30^m$; *HA* at $09^h 00^m$
22	11	00	*HA*	3	15	20	N	E	1	2	Clear	29. *r*	..	
28	06	00	*HA*	2	20	28	N	E	3	2	Clear	29.1*r*	..	
Mar. 2	11	30	*HA*	3	25	28	N 45 W	E	0.5	2	Pt. cloudy	29.5*f*	..	
3	07	00	*RB*	6	*H*	75	N	NE	3	4	Clear	29.6	..	At $11^h 30^m$ had "*S*" shape from SW to NE; changed to *R* at $11^h 50^m$
4	07	30	*RB*	6	10	75	N	NE	4	4	Clear	29.2*f*	..	Intermittent
5	11	00	*HA*	2	15	20	N	E	5	2	Pt. cloudy	29. *r*	..	
6	07	20	*HA*	3	10	15	N 20 W	E	3	2	Clear	29.5*r*	..	
7	05	30	*HA*	5	15	20	N 20 W	E	4	2	Clear	29.8	..	
8	07	40	*HA*	3	25	30	N 20 W	E	4	3	Clear	30. *r*	..	At $09^h 40^m$ half arc from NW
9	05	00	*HA*	2	20	25	N	E	2	2	Clear	30. *f*	..	
10	06	00	*HA*	5	20	25	N 30 W	E	5	3	Clear	29.7	..	
11	07	30	*HA*	10	20	25	N 30 W	E	2	3	Clear	29.7	..	Brightest at $09^h 20^m$; broke into segments at $09^h 30^m$
12	07	00	*HA*	5	20	25	N 20 W	E	9	3	Clear; wind	29.7*r*	..	Snow blowing badly
13	04	30	*HA*	8	25	30	N 45 W	E	3	4	Clear; wind	29.7	..	
14	06	00	*HA*	8	15	20	N	E	6	3	Clear	29.8*r*	12	See photo notes
15	05	00	*HA*	6	15	20	N 45 W	E	8	2	Clear	29.7*f*	..	
16	05	20	*HA*	10	18	22	N 20 W	E	8	3	Clear	29.6*f*	6	See photo notes
17	05	30	*HA*	8	20	25	N 20 W	E	8	4	Clear	29.5	..	
18	09	40	*HA*	8	18	24	N 20 W	E	2	5	Clear; wind	29.3*f*	..	Rather diffuse
19	09	30	*HA*	5	10	15	N 30 W	N 75 E	6	2	Clear	29.2*f*	..	
20	07	50	*HA*	2	10	15	N	E	4	1	Clear	29. *f*	..	Faint all evening
21	06	30	*HA*	6	15	20	N	E	6.5	6	Clear; wind	28.8	..	At $09^h 40^m$ *HA* from NW to *Z* and *D* in N 75 E to E
22	06	40	*HA*	5	5	10	N 20 W	E	1.5	1	Clear; wind	28.9*r*	..	Gone at $08^h 00^m$

Table 1—*Auroral record, College, Alaska, August 9, 1930, to May 7, 1931*—Continued

Date	G.M.T.	Form	Intensity	Altitude		Extension		Duration	Max. area	Weather	Barometer	No. exp.	Remarks
				Lower	Upper	West	East						
1931	*h* *m*			°	°			*h*					
Mar. 23	07 50	*HA*	3	5	10	N 20 W	E	5.5	1	Clear	29.2*f*	..	
25	06 30	*RA*	5	20	30	N	E	5.5	3	Clear	29.6*r*	..	
26	06 45	*RA*	5	20	30	NW	E	7	7	Pt. cloudy	29.5*f*	..	Gone at 08ʰ 00ᵐ; *HA* at 11ʰ 40ᵐ; *RA* at 12ʰ 00ᵐ covering sky
27	11 10	*HA*	2	15	20	N	E	2	3	Cloudy	29.1*f*	..	
28	07 30	*HA*	2	20	25	N	NE	1	2	Cloudy	29. *f*	..	
Apr. 5	07 40	*G*	2	Low	Low	....	NE	2.5	1	V. cloudy	28.6	..	Seen through clouds
7	09 00	*HA*	2	Near *H*	Near *H*	N	NE	1.5	1	Pt. cloudy	28.9	..	
8	09 00	*HA*	2	Near *H*	Near *H*	N	NE	1	1	Pt. cloudy	29. *r*	..	Windy
9	07 40	*HA*	2	20	25	N 20 W	E	4	3	Hazy	29.2*r*	..	Seen poorly through haze; changed to *HB* at 09ʰ00ᵐ
10	08 00	*HA*	8	Near *Z*	Near *Z*	NW	SE	3.5	4	Clear	29 1*f*	..	See photo notes
11	07 20	*HA*	3	25	30	N	E	4	2	Pt. cloudy	28.9	..	See photo notes
13	10 20	*HA*	3	20	25	N	E	1	2	Clear	28.6*f*	..	See photo notes
14	08 00	*G*	2	....	....	....	NE	0.5	1	V. cloudy	28.5*r*	..	
15	09 40	*HR*	3	15	25	N 20 W	E	2	3	Pt. cloudy	28.7*r*	..	
16	08 30	*G*	2	Near *H*	Near *H*	....	NE	0.5	1	V. cloudy	28.8*r*	..	Faint *G* again at 13ʰ 00ᵐ
18	08 30	*HA*	2	35	60	N 20 W	E	3	5	Pt. cloudy	29.7*r*	13	Changed to *HR* at 10ʰ 20ᵐ; see photo notes
20	08 20	*HA*	3	60	70	N 20 W	E	....	6	Cloudy	30.0	..	
21	09 25	*RA*	3	25	40	N	E	1	6	Clear	29.7*f*	..	Came suddenly; motion; color; died out
May 1	10 30	*D*	2	20	90	N	E	0.5	..	Pt. cloudy	29.6*r*	..	Sky very light; wind
3	10 30	*R*	3	20	75	....	NE	1	1	Clear	29.6*r*	..	Sky very light
7	08 30	*R*	3	15	75	....	NE	2	1	Pt. cloudy	29.1*r*	..	Lower end below cloud

Details of photographic auroral log, of methods used to compute distances, and heights of auroras photographed simultaneously at stations 1 and 2 will be given in the second portion of this report to appear in the March 1932 number of the Journal.

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AURORAL OBSERVATIONS AND MAGNETIC CONDITIONS AT THE SITKA MAGNETIC OBSERVATORY, JULY 1930 TO JUNE 1931[1]

By Franklin P. Ulrich

This report is a continuation of the reports,[2] begun in 1923, of the investigation concerning the relation between aurora, the Earth's magnetic field, and radio reception.

Instruments and methods—The instruments and methods as outlined in the report for 1923-24 were used during these observations.

Auroral frequency—The following record is for Sitka and shows the frequency of aurora on clear and partly cloudy nights. Observations were taken up to 23^h and reports after that time were only casual. The number in parentheses indicates the magnetic character for the time observed.

1930, Sept. 5, 6—Clear; no aurora; (1). Sept. 17—Clear; no aurora; (0). Sept. 18—Aurora reported in early hours; (2). Sept. 21—Clear; no aurora; (0). Sept. 22—Clear; steady glow along north sky-line at 23^h; (1). Sept. 23—Clear; no aurora; (0).

1930, Oct. 6—Clear; no aurora; (0). Oct. 7 to 20—Observer on leave of absence, no observations. Oct. 21—Clear; no aurora; (0). Oct. 26—Clear; no aurora; (1).

1930, Nov. 2—Partly cloudy; no aurora; (0). Nov. 3—Partly cloudy; no aurora; (1). Nov. 9—Partly cloudy; no aurora; (0). Nov. 14—Clear at 24^h; no aurora; (0). Nov. 15—Clear; no aurora; (0).

1930, Dec. 7, 8—Partly cloudy; no aurora; (0).

1931, Jan. 6—Clear, no aurora; (0). Jan. 11, 12, 20—Partly cloudy; no aurora; (0). Jan. 21—Clear; no aurora; (0). Jan. 24—Clear; no aurora; (1). Jan. 26—Clear; no aurora; (0).

1931, Feb. 1—Clear to 20^h; no aurora; (0). Feb. 6, 7—Partly cloudy; no aurora; (0). Feb. 12—Partly cloudy with clouds along north sky-line; pale glow above clouds; (0). Feb. 13—Clear; no aurora; (1), Feb. 15—Clear; no aurora; (0). Feb. 25—Partly cloudy; no aurora; (1).

1931, Mar. 3—Clear; no aurora; (0). Mar. 5—Partly cloudy; no aurora (0). Mar. 8, 9, 10, 11—Clear; no aurora; (0). Mar. 12—Clear; no aurora; (1). Mar. 14—Clear at 23^h; no aurora; (0). Mar. 16—Partly cloudy; no aurora; (0). Mar. 17—Clear; no aurora; (0). Mar. 24, 25, 27—Clear; no aurora; (1). Mar. 28—Clear; no aurora; (0). Mar. 30—Clear; no aurora; (no record). Mar. 31—Clear; no aurora; (0).

1931, Apr. 7—Clear at 24^h; no aurora; (0). Apr. 8—Clear; very pale glow along north sky-line; (0). Apr. 10—Clear 23^h to 24^h; no aurora; (1). Apr. 18—Clear; no aurora; (0). Apr. 19—Clear; no aurora; (1). Apr. 20—Clear; no aurora; (0). Apr. 21—Clear; no aurora; (1). Apr. 22, 23, 24—Clear; no aurora; (0). Apr. 25—Clear; pale glow in north sky at 22^h; (1).

1931, May 16—Partly cloudy; no aurora; (0).

Summary—During the past year there was no visible aurora seen by the observer except four pale glows along the north sky-line which were seen on September 22, 1930, February 12, 1931, April 8, and April 25, 1931. Aurora was reported seen only once, on the morning of September 18, 1930.

Of the four pale glows noted above, two occurred on magnetically calm or (0) days and the other two occurred on magnetically (1) days.

[1]Published by permission R. S. Patton, Director, United States Coast and Geodetic Survey.

[2]For previous reports see Terr. Mag., **30**, 150-151 (1925), **33**, 162-165 (1928) **34**, 301-302 (1929), and **36**, 239-241 (1931).

The aurora reported on the morning of September 18 occurred during a (2) day.

In addition to the four glows that were noticed, there were 54 nights that were clear or partly cloudy so that aurora could have been observed if it was visible. Of these 54 nights there were 40 magnetically calm or (0) periods and the other 14 were magnetically (1) periods. There were no magnetic storms or (2) periods on any of the clear nights.

Sitka Magnetic Observatory,
Sitka, Alaska

REVIEWS AND ABSTRACTS

(See also page 317 and 340)

Nolan, J. J., and P. J. Nolan: *Observations on atmospheric ionization at Glencree, Co. Wicklow.* Dublin, Proc. R. Irish Acad., A, v. 40, 1931 (11-59).

The observations were carried out at Glencree, 18 km south of Dublin, between October 1928 and December 1930. Measurements of small ions and condensation-nuclei were made, in general, twice a month except during the summer, when they were less frequent. Each visit to the observing station lasted about two days. Until November 1929, observations were made from 8^h till 24^h each day, and thereafter throughout the 24 hours. The concentration of nuclei (Z) was determined with an Aiken pocket-counter, values as low as 40 and as high as 43,000 per cc being obtained, the high values being found in air coming from the direction of Dublin. The small ion-content of the atmosphere was measured by means of an instrument with a single-fiber electrometer, which made possible a reduction in the average number of large and intermediate ions captured. The average number of small positive ions ($n+$) was about 495 and the average number of small negative ions ($n-$) about 369 per cc. Rain diminished the values of $n+$ and increased the values of $n-$ but produced no marked effect on the value of Z. Evidence of systematic diurnal variations of $n+$, $n-$, and of Z was found. The value of the ratio $n+/n-$ showed a diurnal variation, corresponding to that of the universal potential gradient.

The small ion-counting instrument used at Glencree was compared with an Ebert ion-counter, and a certain discrepancy was found. Observations with both instruments showed that the relative concentration of intermediate ions increased with decreasing concentration of small ions. The formula $q=\alpha n^2+2\eta_2 nN_\pm$ gives values of q, the rate of production of ions per cc, which are much too low, except for high values of $N\pm$ or Z. The empirical formula $q=\alpha n^2+\zeta n\sqrt{Z}$, while not completely satisfactory, accounts better for the relations between n and Z. There is evidence that q has a diurnal variation, resembling that of the universal potential gradient.

The lowest values of Z are considerably smaller than the lowest values of condensation-nuclei found over the ocean on board the *Carnegie*. It seems to the reviewers that the difference may be accounted for as resulting from a combination of two factors, both tending to produce lower observed values than was the case over the oceans. The two factors, briefly mentioned, are: (1) Taking nuclei-counts in air after it had passed through a system of condensers, even though all parts were earthed, instead of in the outside air as was the case of the *Carnegie*; (2) including in the counts only those nuclei falling on the first expansion instead of those falling on all expansions as was done on the *Carnegie*. Experiments carried out by the reviewers have shown that in the neighborhood of ten per cent of the nuclei may be lost in passing through an earthed condenser-system. Other experiments have shown that it is necessary to include in the counts nuclei falling on all expansions and not on the first alone.

The small ion-counting apparatus employed in this work reduces the error due to the capture of intermediate and large ions, but there is some danger of an error due to the collection of ions by the earthed, uninsulated portion of air-flow tube. The Swann modification of the Ebert ion-counter, as used by the Department of Terrestrial Magnetism for all their land work and aboard the *Carnegie*, reduces to the same extent the danger of capture of intermediate and large ions and at the same time eliminates any error due to ions going to other parts of the apparatus.

G. R. Wait and O. W. Torreson

MAGNETIC ACTIVITY—SOME RESULTS OF THE MEASURE ADOPTED AT STOCKHOLM

By C. R. Duvall

In accordance with the report of Dr. A. Crichton Mitchell, adopted at the Stockholm meeting in August 1930, considerable work has been done by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in working up results of the measure adopted for trial. In addition to a fair amount of work on the first half of 1931, the two years 1929 and 1930 have been completed for the Department's two observatories, Watheroo (latitude 30° 19′ south, longitude 115° 53′ east, 244 meters above sea-level) and Huancayo (latitude 12° 03′ south, longitude 75° 20′ west, 3,350 meters above sea-level). As traces of declination, D, horizontal intensity, H, and vertical intensity, Z, are made at these observatories the measure, namely, $(HR_H+ZR_Z)/10{,}000$, was computed. Ranges for the Greenwich day were worked to the nearest γ (0.00001 C. G. S. unit) and three figures only were used in H and Z. The resulting values of the measure were carried to units of the above expression, which results in considerable uncertainty in the last figure. For this figure to be free from errors of computation, the ranges should be carried to 0.1γ, and shrinkage- and temperature-corrections should be applied. This would be of equal if not greater refinement than that used in making the tabulations of the hourly values, and it is not thought such accuracy was meant to be required. In fact, there seems good reason to advocate using 100,000 as the denominator in the above expression, that is, using numbers one-tenth as large; for the two years at the two observatories this would have given numbers ranging between 13 and 182, nearly a hundred times as large as the international character-numbers.

Table 1 gives the monthly means of the Mitchell measure of activity for the two years at the two observatories, along with Bartels' u-measure of activity (inter-diurnal variability), averaged for Watheroo, Honolulu, and Tucson. These values are shown graphically in Figure 1.

Table 1—*Monthly means of* $(HR_H+ZR_Z)/10{,}000$ *and of u-measure of magnetic activity at the Watheroo and Huancayo observatories*

Month	1929 Watheroo	1929 Huancayo	1929 u-measure	1930 Watheroo	1930 Huancayo	1930 u-measure
January	428	624	0.84	524	676	0.79
February	501	681	1.50	523	648	0.82
March	469	710	1.66	527	649	0.88
April	389	604	0.82	565	685	0.84
May	353	474	0.85	497	558	1.13
June	265	409	0.80	466	480	1.01
July	367	505	0.99	426	462	0.70
August	417	502	1.01	456	480	0.77
September	423	568	0.89	527	569	1.43
October	515	668	1.00	539	553	1.31
November	508	583	1.01	471	489	1.01
December	539	664	1.21	431	447	1.25

For the two years the correlation-coefficients between the 24 monthly means are as follows:

Watheroo range-measure and Huancayo range-measure	0.67
Watheroo range-measure and u	0.32
Huancayo range-measure and u	0.28

At the suggestion of Dr. Bartels, the above 24 values of the monthly means of the adopted measure were adjusted to his u-measure, given above, for the two observatories by the form

$$y=a+bx$$

y representing the adopted measure and x the u-measure. Figure 2 gives the residuals for the two observatories, showing, as was expected, the seasonal change common to the two observatories. It seems very probable that a large part of the high correlation of 0.67 between the 24 values at the two observatories is due to this common seasonal change. The seasonal change is also shown to be common in Figure 1.

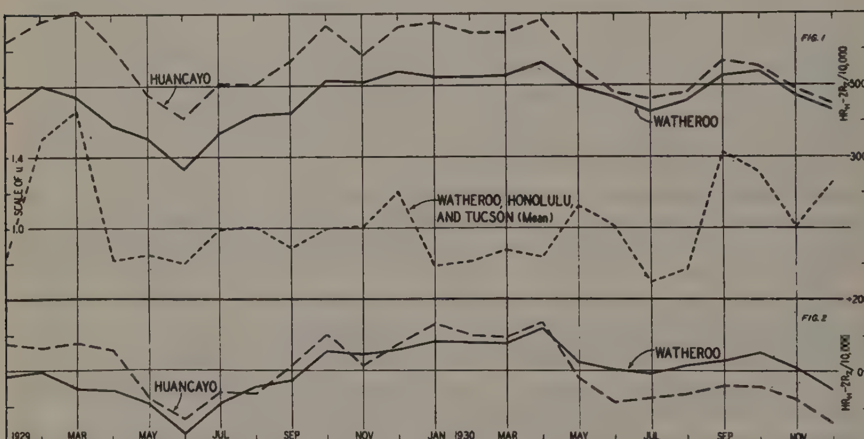

FIG. 1—Monthly mean values of $(HR_H+ZR_Z)/10,000$ for Watheroo and Huancayo observatories and of the average u-measure of magnetic activity for Watheroo, Honolulu, and Tucson obervatories, 1929 and 1930

FIG. 2—Residuals after adjusting range-measure $(HR_H+ZR_Z)/10,000=y$ to the u-measure$=x$ by the form $y=a+bx$, Watheroo and Huancayo observatories, 1929 and 1930

The daily values of the adopted measure for the two years were compared by seasons with the corresponding values of the international character-numbers. For example, the means of the adopted measure for all days of January, February, November, and December, 1929 and 1930, which had respective character-numbers of 0.0, 0.1, 0.2, ... , 2.0, were taken, and these 21 means compared with the respective character-numbers. Figure 3 shows the result of these comparisons. Table 2 gives the values of these means.

TABLE 2—*Simultaneous daily values of international character-numbers and of* $(HR_H+ZR_Z)/10{,}000$, *Watheroo and Huancayo observatories, 1929 and 1930*

International character-numbers	Number of days			Watheroo means for			Huancayo means for		
	Summer	Winter	Equinoxes	Summer	Winter	Equinoxes	Summer	Winter	Equinoxes
0.0	21	11	9	360	313	342	430	376	514
0.1	23[a]	13	12	420	269	353	509	419	538
0.2	15	16	15	405	252	356	501	351	552
0.3	25	26	11	441	262	364	502	408	598
0.4	17	20	16	422	296	354	510	462	550
0.5	12	19	20	417	306	383	551	426	574
0.6	14	16	18	408	285	385	590	468	606
0.7	17	14	15	468	356	388	582	422	605
0.8	16[b]	12	11	466	372	459	591	511	620
0.9	10	8	16	507	366	475	684	514	611
1.0	11	18	14	496	459	482	693	468	638
1.1	13[c]	19	21	550	481	551	700	516	635
1.2	7	20	10	607	491	546	667	570	691
1.3	10	6	13	594	590	581	697	624	653
1.4	6	4	13	665	634	637	986	513	711
1.5	7	8	7	640	666	742	755	657	700
1.6	6	5	8	719	719	697	624	739	712
1.7	3	6	8	816	902	886	937	604	763
1.8	2	3	4	842	1091	900	898	820	938
1.9	5	2	1	1046	1268	1497	1100	904	726
2.0	..	..	2	....	....	1344	....	...	929

[a]22 days only for Huancayo. [b]14 days only for Huancayo. [c]12 days only for Huancayo.

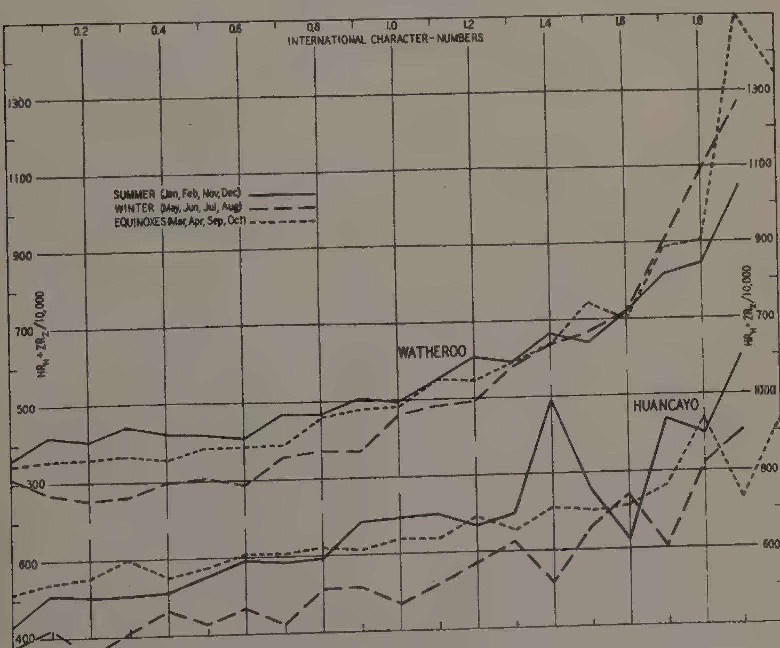

FIG. 3—Simultaneous daily values of international character-numbers and of $(HR_H+ZR_Z)/10{,}000$, Watheroo and Huancayo observatories, 1929 and 1930

As Figure 3 shows, the values of the new measure, which correspond to given international character-numbers, are systematically higher in summer than in winter, especially on the quiet days. At Watheroo in summer, days with an international character-number 0.1 give an average value of 420; this value in winter is only attained by much more disturbed days with international character-numbers over 0.9. This was to be expected, since on quiet days the range is nearly entirely caused by the regular diurnal variation which in summer has a larger amplitude than in winter.

The adopted measure has therefore a systematic seasonal variation which is not due to a change in activity in the usual sense. It seems, therefore, that some such correction for periodic variation as, for instance, suggested by Ad. Schmidt[1] ought to be applied before accepting the new measure as a supplement to the international character-numbers.

The question whether there is a systematic seasonal difference at disturbed times, for example, when the character-numbers are greater than 1.3, must be deferred until data for a greater number of disturbed days are available.

[1]Met. Zs., **33,** 481-492 (1916).

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MAGNETIC SECULAR VARIATION FOR EPOCH 1930

By C. C. Ennis

In the Journal for September 1931 appeared a paper by J. Bartels on geophysical stereograms. It was the privilege of the writer to assist in the computations incident to the construction of the various stereo-

Table 1—*Magnetic elements and their secular changes for epoch 1930*

Long. east °	D °	H c.g.s.	I °	X c.g.s.	Y c.g.s.	Z c.g.s.	ΔD ′	ΔH γ	ΔI ′	ΔX γ	ΔY γ	ΔZ γ
	Latitude 60° north											
0	−14.2	.148	72.0	.143	−.036	.456	+12	−10	+ 1	+ 3	+52	+ 19
20	− 1.9	.150	71.5	.150	−.005	.448	+12	−30	+ 2	−28	+53	+ 19
40	+ 6.8	.152	72.3	.151	+.018	.476	+ 7	−46	+ 4	−49	+25	+ 33
60	+13.5	.150	73.6	.146	+.035	.510	0	−57	+ 4	−55	−13	+ 41
80	+13.1	.148	74.5	.144	+.034	.534	− 3	−52	+ 3	−48	−24	+ 17
100	+ 6.6	.145	75.0	.144	+.017	.541	− 4	−40	+ 2	−38	−24	− 11
120	− 7.6	.149	74.8	.148	−.020	.548	− 6	−23	+ 2	−26	−23	+ 16
140	−11.8	.164	73.6	.161	−.034	.558	− 6	− 3	+ 1	− 9	−28	+ 55
160	− 4.6	.179	71.4	.178	−.014	.532	− 4	+ 8	+ 1	+ 6	−21	+ 75
180	+ 7.9	.181	70.2	.179	+.025	.503	− 3	+10	0	+12	−14	+ 51
200	+19.4	.172	71.8	.162	+.057	.523	− 1	− 5	0	− 3	− 6	− 5
220	+31.2	.145	75.2	.124	+.075	.548	0	− 8	0	− 7	− 4	− 30
240	+36.0	.107	79.8	.087	+.063	.595	− 2	− 7	0	− 2	− 9	− 19
260	+18.8	.063	83.8	.060	+.020	.580	− 3	− 2	0	0	− 6	+ 13
280	−32.0	.063	83.6	.053	−.033	.562	0	+10	− 1	+ 8	+ 5	−102
300	−45.5	.099	79.9	.069	−.071	.555	+ 5	+20	− 2	+24	− 4	−122
320	−38.8	.126	76.5	.098	−.079	.525	+ 9	+22	− 2	+38	+12	− 43
340	−27.5	.141	73.7	.125	−.065	.482	+12	+ 8	0	+30	+40	+ 12
	Latitude 40° north											
0	−10.8	.238	56.0	.234	−.044	.352	+ 9	+ 8	− 2	+20	+60	− 26
20	− 3.0	.249	54.5	.249	−.013	.349	+10	−10	+ 1	− 6	+73	+ 12
40	+ 3.0	.257	55.0	.257	+.013	.368	+ 7	−27	+ 4	−30	+51	+ 61
60	+ 5.5	.268	56.7	.267	+.026	.407	0	−33	+ 7	−33	− 3	+131
80	+ 2.4	.275	57.9	.275	+.012	.437	− 3	−35	+ 4	−34	−26	+ 63
100	+ 0.2	.288	58.0	.288	+.001	.461	− 4	−20	+ 2	−20	−34	+ 28
120	− 5.6	.287	57.0	.286	−.028	.442	− 3	−10	+ 1	−12	−24	+ 7
140	− 7.1	.282	54.7	.280	−.035	.398	− 2	0	0	− 2	−16	0
160	− 0.7	.268	51.4	.268	−.003	.335	− 2	− 4	0	− 4	−16	− 11
180	+ 8.2	.253	53.0	.250	+.036	.336	0	−10	− 1	−10	− 1	− 30
200	+15.3	.244	56.6	.235	+.064	.371	0	−18	0	−17	− 5	− 39
220	+19.4	.242	60.7	.228	+.080	.431	0	−21	0	−20	− 7	− 52
240	+18.8	.235	64.8	.223	+.076	.501	− 1	−26	0	−22	−15	− 55
260	+11.6	.209	69.5	.205	+.042	.558	− 2	−31	+ 1	−28	−18	− 33
280	− 5.0	.184	71.9	.183	−.016	.563	− 4	−38	+ 1	−40	−18	− 61
300	−20.9	.182	70.1	.170	−.065	.502	− 2	−23	0	−25	− 2	− 86
320	−24.5	.203	65.0	.185	−.084	.434	+ 2	+ 3	− 5	+ 8	+10	−159
340	−19.0	.224	60.2	.212	−.073	.392	+ 8	+23	− 4	+39	+42	− 65
	Latitude 20° north											
0	−10.6	.317	25.8	.312	−.058	.153	+ 7	+12	− 6	+24	+61	− 68
20	− 4.4	.327	22.0	.326	−.025	.132	+ 7	+15	0	+20	+65	+ 1
40	+ 0.5	.341	23.0	.341	+.002	.145	+ 4	+ 2	+ 5	+ 2	+40	+ 57
60	+ 0.9	.355	26.0	.355	+.006	.173	− 1	+ 5	+ 8	+ 5	−10	+105
80	− 1.0	.376	27.5	.376	−.007	.196	− 2	+32	+ 3	+32	−22	+ 60
100	− 0.5	.390	24.8	.390	−.003	.180	− 2	+31	0	+31	−17	+ 13
120	− 0.6	.371	25.6	.371	−.004	.178	− 1	+15	− 1	+15	−11	− 10
140	− 0.3	.343	25.2	.343	−.002	.162	0	+ 8	− 2	+ 8	− 5	− 18
160	+ 4.1	.315	26.0	.314	+.022	.154	0	0	− 2	0	0	− 23
180	+ 9.4	.297	31.3	.293	+.048	.181	+ 1	−18	− 1	−19	+ 6	− 23
200	+ 9.3	.293	36.8	.289	+.048	.219	+ 1	−30	+ 1	−31	+ 4	− 12
220	+ 8.6	.304	39.2	.301	+.045	.248	+ 2	−38	+ 2	−40	+12	− 6
240	+ 8.8	.315	42.9	.311	+.048	.293	+ 3	−46	+ 1	−50	+20	− 26
260	+ 9.1	.313	47.6	.309	+.050	.343	+ 4	−61	+ 3	−66	+26	− 7
280	+ 2.7	.288	52.2	.288	+.014	.371	+ 2	−85	+ 7	−86	+13	+ 40
300	− 9.1	.269	53.2	.266	−.042	.360	− 6	−60	+ 3	−67	−37	− 15
320	−19.0	.273	47.8	.258	−.089	.301	− 4	− 3	− 8	−14	−33	−148
340	−18.0	.294	35.3	.280	−.091	.208	+ 2	+20	−11	+24	+10	−130

TABLE 1—*Magnetic elements and their secular changes for epoch* 1930—Continued

Long. east °	D °	H c.g.s.	I °	X c.g.s.	Y c.g.s.	Z c.g.s.	ΔD ′	ΔH γ	ΔI ′	ΔX γ	ΔY γ	ΔZ γ
	Equator											
0	−15.4	.287	−18.7	.277	−.076	−.097	+ 6	−25	−12	−11	+55	− 98
20	− 7.3	.295	−24.0	.293	−.038	−.131	+ 9	−17	− 4	− 7	+79	− 37
40	− 2.1	.314	−23.0	.314	−.012	−.133	+ 8	−11	+ 4	− 8	+74	+ 46
60	− 2.9	.338	−18.0	.338	−.017	−.110	− 6	0	+ 6	− 3	−59	+ 61
80	− 5.2	.359	−19.5	.358	−.032	−.127	− 5	+30	+ 2	+25	−55	+ 7
100	− 0.9	.383	−19.9	.383	−.006	−.139	− 2	+22	− 1	+22	−17	− 22
120	+ 2.5	.389	−17.7	.389	+.017	−.124	0	+10	− 3	+10	+ 4	− 38
140	+ 4.1	.372	−14.5	.371	+.027	−.096	0	0	− 4	0	+ 5	− 46
160	+ 7.0	.361	−11.1	.358	+.044	−.071	+ 1	−10	− 4	−11	+ 9	− 42
180	+ 9.0	.354	− 4.1	.350	+.055	−.025	+ 1	−12	− 2	−14	+ 8	− 15
200	+ 8.0	.345	+ 1.5	.342	+.048	+.009	+ 1	−17	+ 1	−18	+ 8	+ 13
220	+ 8.7	.344	+ 3.8	.340	+.052	+.023	+ 2	−27	+ 4	−30	+16	+ 38
240	+ 9.1	.341	+ 6.2	.337	+.054	+.037	+ 2	−32	+ 2	−35	+14	+ 16
260	+ 9.5	.332	+12.0	.327	+.055	+.071	+ 3	−33	+ 4	−37	+23	+ 30
280	+ 6.4	.319	+21.7	.317	+.036	+.127	0	−28	+ 9	−28	− 3	+ 90
300	− 4.8	.297	+26.5	.296	−.025	+.148	−12	− 5	+ 6	−14	−103	+ 59
320	−16.5	.288	+19.2	.276	−.082	+.100	− 9	0	−10	−21	−72	− 99
340	−18.7	.289	− 0.3	.274	−.093	−.002	− 2	−16	−16	−21	−11	−134
	Latitude 20° south											
0	−24.7	.203	−45.9	.184	−.085	−.209	+ 1	−53	−11	−46	+28	− 85
20	−16.8	.197	−54.1	.189	−.057	−.272	+10	−70	− 8	−50	+75	− 30
40	− 8.3	.202	−55.3	.200	−.029	−.291	+10	−51	− 1	−42	+66	+ 55
60	−11.5	.220	−52.8	.216	−.044	−.290	−11	−41	+ 2	−54	−61	+ 98
80	−16.0	.255	−53.0	.245	−.070	−.339	−14	−31	+ 1	−58	−91	+ 62
100	− 7.2	.287	−53.3	.285	−.036	−.385	− 6	−22	− 1	−28	−43	+ 11
120	+ 0.8	.315	−52.0	.315	+.004	−.403	0	−23	− 3	−23	+ 2	− 34
140	+ 5.2	.333	−48.9	.332	+.030	−.383	+ 1	−23	− 4	−24	+10	− 52
160	+ 9.1	.335	−46.2	.331	+.053	−.348	+ 2	−22	− 4	−24	+13	− 54
180	+11.1	.337	−41.8	.331	+.065	−.301	+ 2	−20	− 2	−24	+20	− 10
200	+11.5	.330	−36.7	.323	+.066	−.246	+ 3	−16	+ 1	−22	+28	+ 24
220	+11.6	.320	−33.8	.314	+.064	−.214	+ 4	−14	+ 4	−21	+34	+ 63
240	+12.0	.312	−30.3	.305	+.065	−.182	+ 4	−16	+ 2	−22	+28	+ 36
260	+13.2	.301	−24.5	.293	+.069	−.137	+ 2	−21	+ 2	−26	+16	+ 36
280	+11.3	.285	−15.2	.280	+.056	−.078	− 3	−20	+ 5	−15	−26	+ 50
300	− 0.5	.263	− 8.2	.263	−.002	−.038	−10	−26	0	−27	−76	+ 8
320	−15.6	.242	−14.2	.233	−.065	−.061	− 9	−32	−11	−48	−52	− 73
340	−24.5	.223	−31.0	.203	−.092	−.134	− 5	−39	−14	−49	−13	−100
	Latitude 40° south											
0	−28.5	.178	−57.1	.156	−.085	−.276	0	−97	− 9	−86	+44	− 13
20	−25.9	.148	−64.6	.133	−.065	−.312	+10	−120	− 8	−89	+91	+ 75
40	−23.3	.140	−66.2	.129	−.055	−.318	+10	−96	− 5	−73	+74	+ 88
60	−27.8	.157	−65.6	.139	−.073	−.345	− 3	−68	− 2	−67	+20	+110
80	−34.5	.180	−67.5	.148	−.102	−.434	−12	−51	0	−76	−21	+137
100	−26.2	.180	−70.7	.161	−.080	−.515	− 7	−44	0	−56	−15	+135
120	− 7.8	.187	−71.8	.185	−.025	−.568	0	−37	− 1	−37	+ 2	+ 57
140	+ 5.8	.204	−70.4	.203	+.021	−.573	+ 1	−31	− 2	−31	+ 3	+ 3
160	+13.5	.228	−67.9	.222	+.053	−.561	+ 3	−30	− 2	−34	+12	+ 4
180	+16.8	.247	−64.1	.236	+.071	−.509	+ 5	−30	− 1	−39	+26	+ 24
200	+17.3	.260	−60.6	.248	+.077	−.460	+ 6	−30	0	−42	+33	+ 53
220	+17.5	.272	−57.3	.259	+.082	−.424	+ 6	−25	+ 2	−38	+38	+ 98
240	+18.7	.278	−53.6	.263	+.089	−.378	+ 5	−25	+ 2	−37	+30	+ 87
260	+21.1	.277	−49.0	.258	+.100	−.319	+ 2	−30	+ 2	−35	+ 8	+ 72
280	+18.3	.267	−40.8	.253	+.084	−.230	− 3	−51	+ 2	−42	−37	+ 71
300	+ 6.1	.246	−34.5	.245	+.026	−.169	− 8	−82	− 1	−76	−62	+ 44
320	−10.1	.222	−36.5	.218	−.039	−.164	− 7	−70	− 7	−77	−32	− 18
340	−22.3	.201	−46.8	.186	−.076	−.213	− 4	−72	−10	−76	+ 6	− 52

grams accompanying that paper, and it seems a worth-while contribution in the field of magnetical investigation to make available the data employed in the construction of stereogram 8 which shows the secular variation of the magnetic field-vector at the intersections of the meridians 0°, 20°, 40°, etc, with the circles of latitude 60° N, 40° N, ... 40° S.

As the resulting salient features of the secular variation were pointed out by Bartels, it is intended herein to give only the data upon which the stereogram depends. These are embodied in Table 1.

The values of the declination (D), horizontal intensity (H), and inclination (I) were scaled from the magnetic charts issued by the United States Hydrographic Office for the epoch 1930. The values of the annual change in D, H, and I, and designated by $\triangle D$, $\triangle H$, and $\triangle I$, respectively, were scaled from the isoporic charts for the epoch 1925 prepared by H. W. Fisk[1] of the Department of Terrestrial Magnetism. The quantities X, Y, and Z denoting, respectively, the north-south component, east-west component, and vertical intensity, were computed from the formulæ

$$X = H \cos D$$
$$Y = H \sin D$$
$$Z = H \tan I$$

The required vector-components were obtained by means of the formulæ

$$\triangle X = \triangle H \cos D - Y \triangle D \sin 1'$$
$$\triangle Y = \triangle H \sin D + X \triangle D \sin 1'$$
$$\triangle Z = \triangle H \tan I + H \sec^2 I \triangle I \sin 1'$$

[1]Isopors and isoporic movements. Comptes-Rendes Assemblée de Stockholm, 1930, Internat. Geod. Geophys. Union, Sec. Terr. Mag. Electr., pp. 280-292, Paris, 1931.

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REVIEWS AND ABSTRACTS

(See also pages 310 and 340)

MAURAIN, CH.: *Comptes-Rendus de l'Assemblée de Stockholm* 15-23 *août* 1930, publiés par les soins de Ch. Maurain. Bull. No. 8, Section de Magnétisme et Electricité Terrestres, Union Géodésique et Géophysique Internationale. Paris, Les Presses Universitaires de France, 1931 (x+479). 23 cm.

The International Union of Geodesy and Geophysics was established at Brussels in 1919. Since that time it has held four general assemblies: Rome (1922), Madrid (1924), Prague (1927), and Stockholm (1930). The present volume contains the transactions of the meetings of the Section of Terrestrial Magnetism and Electricity held in Stockholm in August 1930. By reason of the international character of the Union, these transactions constitute, in a large measure, a record of the progress in the subjects represented, during the three-year interval between the last two meetings. In this connection, it is gratifying to note that, on the invitation of the Union, representatives of Germany were present at the meetings of the Section at Stockholm, one of whom presented there a report on the magnetic work in his own country.

In the transactions before us the general plan of the previous volumes has been followed. The contents which on account of increased interest in the sciences represented as indicated by the growth of the Section, are more voluminous than in previous cases, are divided into six parts, the first of which is of a general introductory character containing the statutes of the Union, lists of the officers, adhering countries, delegates, minutes of the meetings, address of the vice-president, and report of the secretary of the Section.

In Part II are given the reports of the national committees of 19 different countries. In the cases of some countries, as for example, Canada, Great Britain, and the United States, separate reports from several organizations were submitted. These reports taken together constitute the best possible summary of the work accomplished in terrestrial magnetism and electricity during the period 1927-30.

At the Prague Assembly in 1927, a number of commissions were appointed to study and report on special subjects. The reports of these commissions are printed in Part III and deal with (1) magnetic characterization of days, (2) auroral atlas (this atlas

of auroral forms containing 48 photographic reproductions representing the different types and a scheme of visual observations of auroras was submitted to the Section), (3) relations of the International Meteorological Organization and the International Union of Geodesy and Geophysics, and (4) nomenclature and symbols in terrestrial magnetism and electricity. (The terminology expressed in French and English with corresponding symbols occupies nearly four pages of the transactions.)

Part IV is devoted to communications on various items of the agenda. The first 24 pages contain the comments presented by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. These are then followed by comments from various sources grouped under the headings: Terrestrial magnetism, atmospheric electricity, and polar aurora. This section of the volume which is the longest of them all is particularly valuable since it represents an international exchange of views on questions of fundamental importance.

Part V is given over to questions treated jointly with other sections. Among these questions is that of the Polar Year discussed with the Section of Meteorology, relations with the International Union of Scientific Radiotelegraphy, and application of geophysical methods to the study of the underground which was considered jointly with the sections of Geodesy and Seismology.

Part VI is concerned with the constitution of commissions, appointment of reporters, and resolutions adopted. In addition to appointing new members on commissions already existing, two new commissions were created, one of which is to consider the selection of suitable sites for new observatories and to effect a better coordination of the work of existing observatories in Europe, the other to study means of securing well-distributed data for the investigation of the secular variation. Two reporters were also appointed, Prof. S. Chapman on a project of international collaboration for promoting the study of lunar effects on geophysical phenomena and Prof. Cabrera on the question of theoretical studies of terrestrial magnetism. The resolutions passed refer to the adoption of recommendations regarding certain formulas for the numerical characterization of days, inclusion of atmospheric-electric and earth-current observations in the programs of certain observatories, the sending of interesting observations of the various forms of lightning to E. Mathias, and of information regarding ion-counters to J. A. Fleming, and finally the distribution of the auroral atlas. At the end of the volume is a list of the addresses of members of the Section of Terrestrial Magnetism and Electricity.

The style and plan of the volume is the same as that of the transactions of previous assemblies. The editing has been well done and, although a large part of the text is in English, we have noted only a few typographical errors. On page 30, the date given for the destruction of the *Carnegie*, should be 1929 instead of 1925, and on page 335, the height indicated for the conducting layer (700 km) is obviously in error. However, these are matters of minor importance and in no way detract from the general excellence of the work.

H. D. Harradon

ABSTRACT OF THE INNSBRUCK MEETING OF THE COMMISSION OF TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY OF THE INTERNATIONAL METEOROLOGICAL ORGANIZATION AND OF THE RESOLUTIONS ADOPTED SEPTEMBER 21-23, 1931[1]

By H. D. Harradon

The meeting of the Commission of Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Organization was opened September 21, 1931, at Innsbruck, Austria, under the presidency of Professor Ch. Maurain. The following countries were represented: Austria, Denmark, Finland, France, Germany, Great Britain, Holland, Poland, and Sweden.

The President's report at the opening session briefly summarized the status of the principal items of the agenda[2] as follows: (1) Concerning publication of the magnetic character-numbers. (2) Relations between the Commission and the Association of Terrestrial Magnetism and Electricty of the International Union of Geodesy and Geophysics. In this connection, the President stated that the members common to both organizations naturally served as a liaison, that there was no other interest in either case except that of science, and that the harmonious functioning of the two bodies was well illustrated by the development of the question of the Polar Year, the most important item on the agenda. (3) The various questions pertaining to the work during the Polar Year in continuation of the actions taken by the International Association at Stockholm, by the Commission at Leningrad, and by the Commission's subcommittees at London. By a detailed examination of the magnetic and electric work which is desirable and through the preparation of resolutions, the Commission could furnish a basis which would assist the Polar Year Commission in organizing the work. (4) The study of the relations of the moon and the magnetic elements on which topic Dr. la Cour was to present a memorandum by himself and Professor Chapman. (5) The question of the location of new observatories for terrestrial magnetism and electricity, with special reference to the work of the special committee to study this matter appointed at the Stockholm meeting of the International Union of Geodesy and Geophysics. The questions of the agenda were then discussed in order by the Commission during five sessions, the concluding session being held September 23, 1931.

Summary of Resolutions Adopted

The results of these deliberations are abstracted in the following summary of the various resolutions adopted.

1. Having taken note of the resolutions adopted at Stockholm by the International Association of Terrestrial Magnetism and Electricity relative to the numerical

[1]Thanks to the courtesy of Professor Ch. Maurain and Dr. D. la Cour, President and Secretary, respectively, of the Commission, in transmitting an advance copy in French of the minutes of the meeting at Innsbruck, it is possible for the Journal to present herewith an English abstract of the chief features of the meeting and of the resolutions adopted prior to the issuance of the official transactions in French which will appear later.—*Ed.*

[2]For preliminary draft, see Terr. Mag., 36, 144 (1931).

characterization of magnetic activity, the Commission charged its Bureau to invite all the observatories contributing to the "Caractère magnétique de chaque jour" published under the auspices of the Commission to send the values $HR_H/10000$ and $ZR_Z/10000$, or $XR_X/10000$, $YR_Y/10000$, and $ZR_Z/10000$ for each Greenwich day, as also the values $(HR_H+ZR_Z)/10000$ or $(XR_X+YR_Y+ZR_Z)/10000$ together with their usual reports on the basis of character-scale 0, 1, and 2. The Commission noted with satisfaction that the Association will contribute up to £100 per year towards the expenses of publishing the above-mentioned values and requested the Royal Institute of the Netherlands to begin this publication as soon as possible. The International Meteorological Organization was requested to vote a supplementary sum in case the £100 should not be sufficient.

2. The opinion expressed by the International Association of Terrestrial Magnetism and Electricity at Stockholm on the relationship between the said Association and the Commission was approved.

3. The Commission noted with satisfaction that the Association of Terrestrial Magnetism and Electricity had formed two sub-commissions charged with considering (1) the selection of sites of new observatories for terrestrial magnetism and electricity and the examination of a net of observatories well distributed over the globe and the distribution of observatory work in Europe, and (2) the question of secular variation over the whole globe. The Commission expressed its wish to collaborate with these sub-commissions and to obtain the support of the International Meteorological Organization in establishing a net of observatories in Europe for the purpose of increasing as much as possible our knowledge without increasing the expense. It regards simultaneous researches of the secular variation over the entire globe to be of extreme importance and recommended that determinations of the magnetic elements be undertaken at the stations which might be indicated by the Association. The value of long series of observations was emphasized and the wish was expressed that governments or authorities consider favorably the continuation of the work of observatories from which long series are already available.

4. The development of geophysics revealing more and more the connections between the various phenomena of nature, the Commission expressed the opinion that it is of extreme importance to organize for simultaneous intensive observations in the various branches of geophysics and requested the International Meteorological Organization to support such collaboration.

5. Having noted the project of international collaboration to advance the study of the effects of the moon on geophysical phenomena presented at the request of the Commission before the Association of Terrestrial Magnetism and Electricity at Stockholm by Messrs. Chapman and la Cour, and that Mr. Chapman had begun extensive computations using a Hollerith machine, further action of the Commission on this question was deferred until the report of Mr. Chapman is received.

6. Having noted that the number of magnetic stations already assured for the Polar Year exceeds considerably the number of observatories previously in operation and in order to obtain a net of stations still more complete, the Commission strongly recommended the establishment of the following magnetic stations: In the arctic regions, Jan Mayen by Austria, east coast of Iceland by Belgium, Myggbukta by Norway, west coast of Iceland by Iceland, Julianehaab by Germany, Kingua Fiord, Ouellen and Nijnikolinsk by U. S. S. R., Kautokaino and Bossekop by Norway, and Bear Island by Poland; in the lower latitudes, a station in Asia Minor by Turkey, stations at Teneriffe and at Fernando Po by Spain, a station in the Belgian Congo by Belgium, and a station at Pará by Brazil.

7. Great satisfaction was recorded over the project of Dr. Knud Rasmussen to establish a magnetic station in the most northerly regions of Greenland.

8. Considering it of first importance for the investigation of the Polar Year that magnetic stations be well distributed in the southern hemisphere, the Commission recommended strongly the establishment of the following stations: Cape Adare and Macquarie Island by New Zealand, Kerguelen Island by France, South Africa and East Africa, Tristan da Cunha by Brazil, New Year's Island by Argentina, Easter Island by Chile, and Graham Land by Falkland.

9. The Commission expressed the desire that Sir Douglas Mawson be approached to secure his collaboration during the Polar Year.

10. The Commission deemed it extremely important that observations of radio-electricity be included in the program of geophysical investigations of the Polar Year and noted with great satisfaction that the International Union of Scientific Radiotelegraphy has charged a committee with the organization of a program, the collection of observations, and the preliminary reductions of the data obtained in this domain.

11. In view of the importance of world-wide extent of Polar-Year investigations,

the Commission expressed the hope that the height and ionization of the Kennelly-Heaviside layer should be measured during the Polar Year not only at Tromsö, Scoresby Sound, Thule, Angmagssalik, in northern Canada, and in Alaska, as recommended by the International Union of Scientific Radiotelegraphy, but also in the Far East, at some stations near the equator, and in the southern hemisphere. It was noted with great satisfaction that the Carnegie Institution of Washington plans such registrations at the Huancayo and Watheroo observatories.

12. Emphasizing the importance of observing signal intensities of the radio-electric transmissions which will be put into effect under the auspices of the International Union of Scientific Radiotelegraphy, the Commission recommends that all stations which can regularly participate during the Polar Year take part in such observations.

13. In view of the importance of studying all anomalous geophysical phenomena which may take place during the Polar Year, the Commission emphasized the desirability of observing atmospherics and signal-intensities every day at selected stations and expressed the desire that such observations be made also in the polar regions.

14. The Commission recorded its opinions that observations of earth-currents will be of great importance for the investigations of the Polar Year and that continuous records of earth-currents will be much preferable to visual observations.

15. The Commission taking note of the memorandum of Mr. Gish on an inexpensive installation for earth-current observations, recorded its opinion that, in the absence of the necessary credits to provide for registrations both of atmospheric electricity and of earth-currents, observations of earth-currents should be preferred, especially at places well situated for such studies.

16. Observations of earth-currents were indicated as desirable during the Polar Year at the following stations in the arctic regions: Point Barrow, Fairbanks, Fort Rae, Chesterfield, Fort Conger, Franz Josef Archipelago, Dickson, and the Lena Delta.

17. It was noted with satisfaction that earth-current records are assured during the Polar Year at Tucson (United States), Huancayo (Peru), Watheroo (Western Australia), New York (United States) and Tortosa (Spain). The Commission recommended that observations be made also at Lerwick, at Jakoutsk, in New Zealand, in Argentina or Chile, in southern India, in Central or South Africa, in Japan or China, and if possible, at stations in the region of the Ross Sea, at Tristan da Cunha, and at Kerguelen Island.

18. Noting with satisfaction that registrations of earth-currents are already organized in the United States by the American Telephone and Telegraph Company, it was resolved (1) that such registrations ought to be made during the Polar Year on some additional lines in the United States and (2) that other telephone and telegraph companies also be asked to cooperate in earth-current measurements at other places well distributed over the Earth.

19. The Commission expressed the desire that observations of atmospheric electricity be made at the greatest possible number of stations and especially at those where auroras and radioelectric phenomena will be observed, as well as at mountain stations.

20. The Commission recorded its opinion that it would be helpful if observatories having kites should make altitude observations of potential gradient on the international days.

21. In view of the vital importance for the Polar-Year work of having instruments suitable for these investigations and a well-trained personnel, the Commission expressed the hope that credits be placed at the disposal of the International Commission of the Polar Year 1932-33 to permit it to support and to promote the preparations wherever necessary.

22. The Commission recommended that all the stations provisionally established for the participation in the Polar Year make use of instruments recording declination, horizontal intensity, and vertical intensity on a time-scale of about 15 mm per hour with scale-values per mm of $1'$ to $2'$, of about 5γ, and of about 5γ in declination, horizontal intensity, and vertical intensity, respectively.

23. The importance of obtaining complete records during great disturbances was emphasized and provision therefore recommended for a supplementary set of less sensitive instruments or for other arrangements to permit photographic records even in the case of great perturbations.

24. For the less sensitive instruments, the Commission recommended the following sensitivities: About $5'$ per mm for declination, about 20γ per mm for horizontal intensity, and about 20γ per mm for vertical intensity. Even for instruments of small sensitivity it was recommended that supplementary sources of light or auxiliary mirrors be provided so as not to lose the record during extraordinarily large disturbances.

25. It was urged strongly that every observatory with more than one set of vari-

ometers have its variometers mutually controlled every day. To obtain such control the Commission recommended making visual readings of the variometers, such observations to be entered immediately on a "control-list."

26. In order to study the relations of the aurora borealis and magnetic perturbations with reference to distance from the magnetic pole, it is deemed extremely important that as complete observations as possible be made to yield data for such study at the following stations situated along the magnetic meridian: Scoresby Sound, east coast of Iceland, Lerwick, Eskdalemuir, Abinger, Val Joyeux, Tortosa, and Hoggar.

27. The Commission emphasized the extreme importance of obtaining continuous high-speed registrations throughout the Polar Year.

28. The Commission regards it imperative in intensive studies of the variations of the Earth's magnetic field to obtain high-speed registrations at as many stations as possible, recommending a time-scale of 180 mm per hour and scale-values per mm of record of about $5\times 3438/H$ for declination, about 5γ for horizontal intensity, and about 5γ for vertical intensity.

29. For stations where the recorder must be adjusted to obtain high-speed registrations, the following days were selected for such registrations, except in the case of changes made necessary by days indicated for special work by other commissions: August 10-11, September 14-15, October 12-13, November 9-10, and December 14-15, 1932; January 11-12, February 8-9, March 8-9, April 12-13, May 10-11, June 7-8, July 12-13, and August 9-10, 1933; and also, if possible, on August 24-25, September 28-29, October 26-27, November 23-24, and December 28-29, 1932; and on January 25-26, February 22-23, March 22-23, April 26-27, May 24-25, June 21-22, July 26-27, and August 23-24, 1933.

30. The Commission pointed out the importance of making high-speed registrations during entire rotations of the Earth and recommended such registrations during whole Greenwich days and, if it is necessary to reduce the number of days with high-speed registration, to retain the Thursdays of the international days.

31. Since the total eclipse of the Sun takes place on August 31, 1932, the Commission recommended that observations of terrestrial magnetism and electricity be as extensive as on the international days for August 30 and 31 and September 1, or in any case at least for August 31, 1932.

32. The Commission approved the memorandum entitled "Auroral work during the Polar Year 1932-33" presented by the Committee of the Polar Year of the International Union of Geodesy and Geophysics, and expressed the opinion that it will be of great importance to make auroral observations, as complete as possible, at the following systematically distributed stations: (*a*) In the zone of maximum auroral frequency, (1) Tromsö, (2) east coast of Iceland, (3) Julianehaab, (4) east coast of Labrador between 57° and 58° north latitude, (5) west coast of Hudson Bay, (6) Fort Rae, (7) Fairbanks or College, (8) Wrangel Island, (9) island to the north of Siberia, (10) North Land, and (11) Novaya Zemlya; (*b*) near a single magnetic meridian, (12) Lady Franklin Bay, (13) Thule, (14) Godhavn, (15) Godthaab, and (3) Julianehaab; (*c*) near a single geographical meridian and on each side of the auroral zone, (16) Spitzbergen, (17) Bear Island, (1) Tromsö, (18) Dombaas, (19) Oslo, and (20) Husby; (*d*) in a close net in or near the auroral zone, as for example, in the north of Scandinavia.

33. It was recommended that the altitude of the aurora borealis be measured at stations in Scandinavia, in Iceland, in southern Greenland, near the magnetic axis, in Canada, in Alaska, and in the north of Russia at least at Irkutsk, Dickson, and Kandalakscha. The Commission stressed the importance of such measurements at several stations in the north of Scandinavia as well as the organization also of measurements of the height of the aurora australis.

34. Deeming it important that the presence of aurora be observed at as large a number of stations as possible, the Commission recommended that such observations be made at all the magnetic stations, at astronomical observatories, at meteorological stations, and on all ships less than 40° from the magnetic axis of the Earth.

35. The principal hours of observing the presence of auroras were designated to be the same as those of synoptic weather observations, namely, 1:00, 7:00, 13:00, and 18:00, or 19:00 G. M. T., and in addition all stations were invited also to observe auroras at the hours 4:00, 10:00, 16:00, and 22:00 G. M. T.

36. The Commission recommended that the registrations of declination, horizontal intensity, and vertical intensity on the time-scale of 15 mm per hour be measured as soon as possible after the photographic records have been developed and dried and, as far as concerns this preliminary measurement, the mean values for six hours centered at 3^h, 9^h, 15^h, and 21^h G. M. T., should be measured and these values entered on the control-list. The Commission expressed the opinion that these measures may be made

with the aid of a straight line on a transparent plate, but recommended in case of great disturbances that the means for six hours be formed from the hourly or half-hourly mean values.

37. It was recommended that the maximum and the minimum values of each element for each day be entered on the control-list as soon as the photographic record will permit measurements.

38. The Commission recommended that a list of "preliminary results" be prepared at the end of each month from values compiled from the records of that set of variometers designated as the principal set at the station. The base-values adopted for each element, the reduced means, and the reduced maximum and minimum values should be entered for each day.

39. The Commission recommended that visual readings of one set of variometers be made during absolute determinations, that these determinations be computed the same day that they are made, and that the resulting base-values of the variometers be entered immediately on the control-list.

40. That the observers may be kept informed regarding the progress of the great enterprise in which they are taking part, the Commission recommended sending by radio to the Polar-Year stations information regarding the phenomena observed at the different stations.

41. The Commission approved in principle the proposed measures for the publication of observations as presented by the sub-commission on Publication of the International Commission for the Polar Year.

42. The Commission is of the opinion that there will be so many important researches made during the Polar Year which will not be published in the national publications that it is extremely desirable that special credits be placed at the disposal of the International Commission for the Polar Year to facilitate the discussion of the observations by experts and for the publication of the results thus obtained.

43. The Commission entrusted its Bureau with making any necessary editorial corrections in the resolutions adopted regarding the Polar-Year work and also with making further proposals on the question of publication.

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ABSTRACT OF THE INNSBRUCK MEETING OF THE INTERNATIONAL COMMISSION FOR THE POLAR YEAR 1932-33 OF THE INTERNATIONAL METEOROLOGICAL ORGANIZATION AND OF THE RESOLUTIONS ADOPTED SEPTEMBER 23-26, 1931[1]

By H. D. Harradon

The International Commission for the Polar Year 1932-33 held a called meeting at Innsbruck, Austria, September 23-26, 1931, immediately following that of the Commission of Terrestrial Magnetism and Atmospheric Electricity. The following members of the International Commission or their duly accredited representatives were present: Messrs. C. F. Brooks (representing J. A. Fleming), D. la Cour, G. van Dijk, H. Dominik, A. H. R. Goldie (representing G. C. Simpson), H. Hergesell, Th. Hesselberg (representing H. U. Sverdrup), J. Keränen, Ch. Maurain, A. W. Sololoff (representing A. F. Wangenheim), and A. Wallén. Austria, Bulgaria, France, Germany, Great Britain, Holland, Poland, and Sweden were represented by members of their national polar-year commissions. The principal matters brought before the four sessions of the Commission were indicated in the report of President D. la Cour, an abstract of which is given below. Fifty-seven resolutions were adopted as a result of the deliberations of the Commission, and the abstracts of these, also appended, summarize the work accomplished.

Abstract of the President's Report

The first report[2] of the Commission on its work up to the autumn of 1930 was printed and distributed towards the end of the year 1930. Since that time the Commission's activities have been communicated in circular letters to its members. These circular letters (No. 24 was distributed just before the Innsbruck meeting) have been sent not only to members of the Commission but also to other persons and institutions connected with the work, so that the number of addresses to which they are sent is 65. (The table of contents of Nos. 13-20 was published as an appendix to circular letter No. 20, and that of Nos. 21-24 as distributed at the Innsbruck meeting.)

The Sub-Commission on Publication met at London in December 1930 where its chairman, Dr. C. G. Simpson, presented a memorandum which was distributed in January 1931. Besides this memorandum, others dealing with almost all the items on the agenda for the meeting were included as appendices in the circular letters. A popular memorandum entitled "The International Polar Year 1932-1933," prepared by the President and J. M. Stagg of the London Meteorological Office, was also published and distributed.

Some of the features characterizing the past year were reported. It is obvious that all the preparation and all the work of the Commission

[1]The Journal is indebted to Dr. D. la Cour, President of the Commission, for transmitting an advance copy in French of the minutes of the meeting at Innsbruck from which this abstract has been prepared.—*Ed.*

[2]Premier rapport de la Commission Internationale de l'Année Polaire 1932-1933. Leyde, Secrétariat de l'Organisation Météorologique Internationale, No. 6. 1930.

must be limited until the parliaments vote special credits and, until the time that the credits are assured, there is evidently some degree of uncertainty. Grateful thanks are due those countries and institutions which, through definite action, have formed the indispensable vanguard of this enterprise.

The past year has witnessed increasing international collaboration for the purpose of deriving the greatest profit from the work being organized. The collaboration with the International Union of Scientific Radiotelegraphy appears especially valuable from the scientific point of view. Mention also may be made in this connection of the agreement reached in the various branches of geophysics in fixing the same "international days" for the intensification of their observations.

Dr. E. Kidson, Director of the Meteorological Office of New Zealand and Secretary of the New Zealand Polar Committee, and Dr. A. Wallén, Director of the Meteorological Service of Stockholm and Secretary of the Swedish Committee for the Polar Year, have been coöpted as members of the Commission. National Commissions for the Polar Year have been formed in Austria, Belgium, Bulgaria, France, Germany, Great Britain, Holland, Japan, New Zealand, Norway, Poland, Spain, Sweden, and U. S. S. R.

The following remarks on the resolutions indicated by their numbers as adopted at Leningrad in August 1930 and on several questions calling for decision were then submitted.

1. *Beginning and end of the Polar Year*—Some stations cannot be established soon enough to be in full operation August 1, 1932, and it will be necessary to stop the observations at some stations before August 31, 1933, in order that the observers may leave before the winter of 1933-34. However, as there are not many such cases, this seems a matter of secondary importance with respect to the whole work.

No serious objections have then been made to the duration fixed for the Polar Year but it has been proposed from different quarters that the Polar Year be postponed in view of the world financial crisis. On the other hand, several persons have stated that they consider it not only possible but entirely necessary—if a Polar Year is to be undertaken—to realize in 1932-33 the projects planned.

It seems an essential point in deciding this question is that much of the preparation has already been undertaken and that actual work on some stations and equipment has already been begun. Moreover, it is now assured that observations of great value will be secured during 1932-33, so that the question of deferring the Polar Year is rather that of choosing between energetic support of the researches assured and already begun or refusal to support the work begun on the basis of the program adopted and abandonment of the adhesion assured in favor of an uncertain future. It would be fatal in the future for the undertaking of any great enterprise in geophysics to defer the Polar Year, whereas the realization of projects despite the difficulties encountered will inspire respect for future resolutions and facilitate their accomplishment. The feasibility of enterprises should be doubted and their postponement discussed *only before* the decisions are taken.

2. *Zonal time*—In the resolution zonal time was defined as Greenwich mean time plus or minus a number of whole hours. However, it has been proposed to use Greenwich mean time not only for the synoptic

observations but also for the aerological observations, and the Sub-Commission on Publication has proposed using Greenwich mean time for the publication of magnetic and electric data and for auroral observations. It may be mentioned further that the radioelectric observations, which were decided upon later, will also be published according to Greenwich mean time. It follows that zonal time will be employed only for the publication of certain meteorological tables and it would therefore be proper to consider whether it would be advantageous, as regards the Polar Year, to use Greenwich mean time everywhere.

3. *Net of stations*—Of the magnetic stations north of 55° north latitude proposed at the Leningrad conference, sixteen are already established, fourteen are assured, six are probable, and there are only five regarding which no decision has yet been reached.

4. *Recommendation regarding the establishment of contemplated magnetic stations*—Although the net of magnetic stations already assured is of great value, it must not be forgotten that the establishment of those stations not as yet definitively assured as proposed in Resolution 3 is of extreme importance and will enhance greatly the value of observations of the stations already assured.

5. *Magnetic station at Lady Franklin Bay*—It is with the greatest satisfaction that the Commission has taken note of the efforts of Captain Williams to effect the establishment of this important station.

6. *Magnetic stations in Iceland*—It is with equally great satisfaction that the Commission has learned that the Fonds National de la Recherche Scientifique of Belgium is planning the establishment of a magnetic station on the east coast of Iceland and that the Carnegie Institution of Washington has signified its intention of lending instruments to Iceland so that this country may establish the station on its west coast.

7. *Magnetic net in the antarctic*—The establishment of magnetic stations in the antarctic has not yet been assured to the extent that might be desired and it is necessary to put forth all efforts possible to increase the number of stations there. The study of simultaneous magnetic oscillations at the two poles of the Earth is of the greatest importance for magnetic and radioelectric as well as auroral research, and in the absence of sufficient resources in some countries at the extreme south of our globe, we must call upon countries and institutions in the northern hemisphere for support of this work. It is necessary to persuade them that magnetic observations made in the antarctic would render much more valuable observations made in the northern hemisphere.

8. *Renewal of the magnetic stations at New Year's Island*—Argentina has promised to collaborate through the favorably situated station in the South Orkneys, but up to the present time no promise has been given to establish the station at New Year's Island. Observtions at this station situated so near the French stations of 1882-83 are of such importance as to justify the hope that the station will be established with the help of another country or institution.

9. *Magnetic stations at Easter Island, Tristan da Cunha, and Kerguelen*—The question of establishing these three magnetic stations, so well situated in the midst of the three oceans of the southern hemisphere, is well advanced. The commission will be happy to express its congratulations to the three countries, Chile, Brazil, and France, if they succeed in effecting this very important extension of the world net of magnetic stations.

10. *Duration of the magnetic observations*—The duration of the observations at the majority of the magnetic stations provisionally established for participation in the work of the Polar Year is limited for various reasons, but it would be very advantageous to continue the work for some time after the Polar Year at some of these stations. But it would be still more important if some of these stations could be regarded as permanent. In this way, the organization of the Polar Year would contribute greatly to development of the world net of magnetic stations.

In continuation of these remarks, it is natural to add that the intensification of magnetic observations will take place also outside the polar regions, namely, at several of the observatories already in operation, and that a number of stations will be established in regions where observatories are very few at present. Among the observatories in low latitudes of which the establishment is planned are stations in the Canary Islands (Spain), in Belgian Congo (Belgium), and in Somalia (Italy). The new and permanent French stations at Hoggar and Dakar, as well as the three stations mentioned above, mark a considerable progress in the study of magnetic phenomena in Africa. The establishment of a station in South Africa is also strongly to be recommended.

11. *High-speed magnetic registration*—This question was brought before the International Commission of Terrestrial Magnetism and Atmospheric Electricity which was requested to make detailed recommendations on the subject.

12. *Testing of new types of instruments in the polar regions*—It is with great satisfaction that the Commission has taken note of the experiments made at Murmansk by Professor Moltchanoff. Professor Moltchanoff sent up during the winter (January) a number of balloons provided with radio meteorographs constructed by himself. He also took part in the recent expedition of the *Graf Zeppelin* and took advantage of this opportunity for making further experiments with his radio meteorograph.

The Commission expresses its thanks to the director of the Geophysical Observatory at Sodankylä for the opportunity already given foreign investigators to become acquainted with the work at the Observatory under arctic conditions, and thanks are again due for tests at the same observatory of such instruments as it is desirable to use during the Polar Year.

In like manner the Commission notes with gratitude every enterprise for assuring the full success of the Polar-Year observations. It has noted with great satisfaction the sending of an English expedition to Fort Rae, the expedition of M. Charcot with the *Pourquoi-Pas*? to Scoresby Sound, and the despatching of a vessel of the Dutch Navy to Reykjavik.

Emphasizing again the importance of Resolution 12 of Leningrad, it is to be noted that of equal importance with the new types of instruments for polar work is the familiarity of acquaintance of personnel with the instruments and the difficulties to be encountered in the polar work. It is fitting, therefore, to emphasize Resolution 12 that the chiefs of all the arctic stations during the Polar Year understand the conditions of work in these regions and that those who do not know them already make a study of them before the Polar Year at an observatory or station where they may work at low temperatures.

13. *Collaboration of all the magnetic observatories in the world*—As soon as the program has been definitely determined, the Commission will request the directors of all the magnetic observatories in the world to collaborate as far as possible in the program. In addition to this, it is proposed that the Commission request the International Meteorological Organization and the Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics to lend their moral support and to facilitate as much as possible the participation of the observatories.

14. *Catalogues of magnetic determinations in the polar regions*—The Commission has as yet received no information on the progress of this work.[1]

15. *Mountain stations in the arctic regions*—Of the mountain stations proposed for the arctic regions, three are established, ten are probable, and no decision has yet been reached regarding four. It is strongly recommended that one or two mountain stations be established in the vicinity of Bering Strait to permit making correlative studies with observations made in the arctic regions but on the other side of the pole.

16. *Aerological stations in the arctic regions*—It appears that the program of establishing five aerological stations in the arctic regions for the study of the stratosphere is well on the way towards realization. There are good reasons for believing that the station in Alaska will be established at Fairbanks by the United States, the station in Canada at Fort Rae by Great Britain, the station in Greenland at Scoresby Sound by France, and the station in U. S. S. R. by that country. As regards the station at Spitzbergen, it is to be hoped that the "Altmeister der Aerologie," Professor Hergesell, will succeed in finding a solution to this important question. One or two sounding-balloon stations are assured in Canada and it is hoped that the U. S. S. R. will establish still another station in its territories.[2]

17. *Aerological and meteorological observations at sea*—The International Commission for the Exploration of the Upper Atmosphere has also adopted this resolution. The resolution has further been sent to the subcommission for the radio-meteorological organization for the oceans with the request that this question be placed on the agenda of its next meeting in October.

18. *Study of the invasion of polar air*—The Commission is not cognizant of the steps taken by the U. S. S. R. in this connection. At its Madrid meeting in March 1931, the International Commission for the Exploration of the Upper Atmosphere also recommended to the U. S. S. R. the support of these investigations.

19. *Climatological studies*—The report of M. Kaminsky was published in the First Report of the Commission. Several questions pertaining to the climatological investigations were discussed by the Sub-Commission on Publication which took them into consideration when making the proposal on the publication of the meteorological observations.

20. *Hydrological researches*—At its meeting in Copenhagen in March 1931, the International Council for the Exploration of the Sea adopted

[1]In this connection, attention may be called to the following publication by B. P. Weinberg: Catalogue of magnetic determinations over the territory of U. S. S. R. and adjacent countries from 1556 to 1926. Leningrad (1929).

[2]Four stations are assured by the U. S. S. R.

a resolution recommending the intensification of hydrological researches during the Polar Year.

21. *Actinometric researches*—The report of M. Kalitine on the organization of the actinometric work during the Polar Year was published in the First Report of the Commission. The Commission has since received an account of the discussion of this subject at Potsdam in February 1931 at the meeting of the members of the International Commission of Solar Radiation and of the Commission on Radiation of the International Union of Geodesy and Geophysics.

22. *International days of the Polar Year*—At its Madrid meeting in March 1931, the International Commission for the Exploration of the Upper Atmosphere fixed international days for the years 1932 and 1933. It is greatly to be appreciated that the Commission for the Exploration of the Upper Atmosphere has abandoned the old principle of fixing international days in favor of a regular distribution of observation during the two years in question in order to determine the annual course of the elements. However, the Commission has not only decided upon a regular distribution over the whole year, but it has also tried to organize in the best manner the use of all the material available by introducing international days of the second and third orders on which it is preferable to carry out supplementary observations. This is certainly a proper step as far as aerological observations are to be regarded as a part of the geophysical investigation, as has been made immediately evident by the decision of the International Union of Scientific Radiotelegraphy at its Copenhagen meeting, May-June 1931, organizing for the same international days special researches of interesting geophysical phenomena connected with the work of that Union.

It is to be noted that the Commission has received a large number of proposals from various commissions and sub-commissions of international bodies interested in the Polar Year.

It is the duty of the Innsbruck meeting to consider all the proposals made. To this end it seems desirable that all the resolutions and recommendations passed upon at the Innsbruck meeting be collected in a separate chapter of the Commission's next report under the title "Program and recommendations of the International Commission of the Polar Year." Those matters in which final decisions may not be reached until later can then be communicated in supplements. However, to accomplish this, it is necessary that the Commission be capable of taking action. We must provide means by which the Commission may make decisions and act much more quickly than is usually the case for a commission whose members are scattered over the whole globe. Votes by mail have been helpful, but regulations are needed governing the Commission's internal business to advance as much as possible its work. Among the proposals to be offered on this point when discussing item 16 of the agenda, is that by which the Commission may refer to a sub-commission the making of final decisions on behalf of the Commission. Thus an important decision may be made by a minority of the members of the Commission, but, in such a case, it seems indispensable that the decisions be accepted by a large qualified majority. This same point of view seems properly to apply to the whole Commission, since it is almost certain that all the members of the Commission will not be present at the meeting. The regulations of the International Meteorological Organization prescribe

to the commmissions that their decisions be made on the basis of the majority of the votes of the members present except when a vote by countries is required. For the reasons above mentioned these regulations are unfavorable to the functions of the Commission and not in accord with a preceding paragraph of the Statutes which grants to the commissions the organization of their work to suit themselves. Moreover, the faculty of demanding a vote by countries does not seem good in the case of a scientific commission which must endeavor to act as a truly international commission having no other interests in view except those of science. As several of the Commission's members are presidents of international commissions, the President will propose to the Commission that the International Meteorological Organization be asked to permit the Commission to act quickly by dispensing with Section 4 of Article V of the Organization's Statutes.

Summary of Resolutions Adopted at Innsbruck

1. The votes of the Commission are (*a*) by ballot, (*b*) at a meeting, and (*c*) of authorized sub-commissions, the votes being counted in the following manner: For, counts one yes; abstention, counts nothing; against, counts two noes; vote not received counts one no. In case of a vote by correspondence a proposal is accepted when the number of yeas exceeds the number of nays. The Commission may charge a sub-commission with making decisions on behalf of the Commission on certain subjects if these decisions do not conflict with decisions already made by the Commission. The decisions made by a sub-commission must be approved by the President of the Commission in order to become effective. If the President does not approve, the question will be submitted to the whole Commission for vote by correspondence. The members of the Commission have the right of sending a representative if they cannot take part personally in a meeting or session of the Commission. A member desiring to be represented should so inform the President before the meeting or session. Substitutes have the right to vote, but a substitute may represent only one member and a member may not be represented by another member.

2. The Commission expressed its great satisfaction to the interested Ministers of Holland for the preliminary collaboration of the Dutch military authorities to establish an airplane aerological station in Iceland and expressed the wish that the military aerological services of other countries take part, during the Polar Year, in the aerological observations, especially on international days.

3. The Commission, taking note of the resolution of the Permanent Council for the Exploration of the Sea relative to the desirability of making hydrographic observations during the Polar Year, expressed the wish that expeditions comply with the request of the Council.

4-6. These are the same as the Innsbruck resolutions 6-8 of the Commission of Terrestrial Magnetism and Atmospheric Electricity (see p. 320 of this Journal).

7. The Commission expressed the desire that Sir Douglas Mawson be approached for obtaining his collaboration to establish, during the Polar Year, a magnetic and auroral station in the vicinity of the maximum zone of the aurora australis.

8-12. These are the same as the Innsbruck resolutions 10-14 of the Commission of Terrestrial Magnetism and Atmospheric Electricity (see pp. 320-321 of this number of the Journal).

13. The Commission has taken note of the memorandum of Mr. Gish on an inexpensive installation for earth-current observations and is of the opinion that, in the absence of the necessary credits for the registration of both atmospheric electricity and earth-currents, the observations of earth-currents are preferable especially at sites well situat d for these studies.

14-18. These are the same as the Innsbruck resolutions 16-20 of the Commission of Terrestria Magnetism and Atmospheric Electricity (see p. 321 of this number of the Journal).

19. In view of the vital importance for the work of the Polar Year of having instruments suitable for the proposed researches and a well-trained personnel, the Commission expressed the desire that credits be placed at the disposal of the Commission so that it may support and advance the preparations wherever necessary.

20-38. These are the same as the Innsbruck resolutions 22-30 of the Commission

of Terrestrial Magnetism and Atmospheric Electricity (see pp. 321-322 of this number of the JOURNAL).

39. The Commission approved in principle the proposals made for the publication of observations and presented by its Sub-Commission on Publication.

40. The Commission is of the opinion that there will be so many important investigations made during the Polar Year which will not be published in the national publications that it is extremely desirable that special credits be made available to the Commission to facilitate the treatment of the observations by experts and for the publication of the results thus obtained.

41. All stations undertaking aerological observations during the Polar Year are requested to make their observations, as far as possible, at times between 0^h and 2^h, 6^h and 8^h, 12^h and 14^h, and 18^h and 20^h G. M. T. in order to render the observations useful for world-wide investigations as well as for the purposes of commerce and traffic. Thus, besides measurements of the upper winds and the condition of the upper atmosphere, also simple but careful cloud observations have their importance. Every meteorological central office of the Earth is requested to send in a list of the collaborating aerological observation-stations in its territory as soon as possible to the Polar Year Commission and at the latest by March 1, 1932.

42. For the years 1932-33, the following days are fixed as international days of the first order for aerological researches: January 13-14, February 10-11, March 9-10, April 13-14, May 11-12, June 8-9, July 13-14, August 10-11, September 14-15, October 12-13, November 9-10, and December 14-15, 1932; January 11-12, February 8-9, March 8-9, April 12-13, May 10-11, June 7-8, July 12-13, August 9-10, September 13-14, October 11-12, November 8-9, and December 13-14, 1933. On the first day of each month at 18^h to 20^h G. M. T., on the second day of each month at 6^h to 8^h and at 12^h to 14^h G. M. T., simultaneous ascents are to take place over the whole Earth.

43. In consideration of the total solar eclipse in the north polar regions on August 31, 1932, this day is also fixed as an international aerological day of the first order.

44. In order to make further ascents during the Polar Year as useful as possible, the following days are fixed as international days of the second order: January 27-28, February 24-25, March 23-24, April 27-28, May 25-26, June 22-23, July 27-28, August 24-25, September 28-29, October 26-27, November 23-24, and December 28-29, 1932; January 25-26, February 22-23, March 22-23, April 26-27, May 24-25, June 21-22, July 26-27, August 23-24, September 27-28, October 25-26, November 22-23, and December 27-28, 1933. In the same way Wednesday and Thursday, Greenwich reckoning, of the rest of the weeks are regarded as international days of the third order. The fixing of international days of the second and third order should under no circumstances lessen the activity on the international days of the first order. On international days of the second and third orders observations will be made, as on international days of the first order, on Wednesday from 18^h to 20^h, and on Thursday from 6^h to 8^h and from 12^h to 14^h. The period 6^h to 8^h on Thursday will be regarded as the principal time of observation, all according to Greenwich time.

45. The Commission considers that observations at mountain stations during the Polar Year are very important and recommends that observations be made preferably at the following stations: Disco (Godhavn), Godthaab, Arsuk (Ivigtut), Angmagssalik, Scoresby Sound, Snäfell, east coast of Iceland, Slättaratind, Haldde, Fanaråken, Gausta, Spitzbergen, Novaya Zemlya, Franz Josef Land, Jan Mayen, northwest Greenland, Baffin Island, Region of Bering Strait, Ben Nevis or Snowdon, Peak of Teneriffe, Cape Verde, southern Central Europe, Italy, Balkans, station on the airway through Mesopotamia, Central Asia, Northern India, Southern India, Java, Japan, southeast Australia (or Tasmania), Fiji Islands, Hawaii, Alaska, west coast of the United States, Mexico, Central America, Galapagos, northern Chile, Pernambuco, South Africa, Fernando Po, East Africa near the Equator, and Réunion.

46. The Commission considers of great importance for the Polar Year the experiments of Professor Wigand to reach great altitudes in the atmosphere by means of rubber balloons as also those of Colonel Jaumotte with the micro-meteorograph.

47. The Commission considers it very important that the expedition of Dr. Sven Hedin in Central Asia be continued during the Polar Year and that it take part in the work.

48. The Commission is of the opinion that the observations already assured during the Polar Year 1932-33 will be of such great importance that the researches planned should be carried out during 1932-33.

49. The Commission charges its President with communicating as soon as possible with the organizations and persons who can take part during the Polar Year in the southern hemisphere. The plan agreed upon will be communicated to them but with

the specific statement that it is simply for their information and that all assistance will be welcome.

50. For the antarctic stations, accessible only during the warm season, the beginning of the International Polar Year is deferred until January 1, 1933.

51. The Commission requests that at the polar stations all possible care be taken to make sure that the scale-determinations, corrections, and everything necessary for thoroughly utilizing the records shall be made and noted on the sheets during the sojourn in the polar regions and that the discussion also be begun and pursued as far as possible.

52. The Commission requests the Committee to urge the different national meteorological services to develop to the maximum during the Polar Year the publication of the daily synoptic observations.

53. The Commission is of the opinion that the issuing of the weather map of the northern hemisphere during the Polar Year is necessary to further the discussion of the meteorological results and hopes that such maps may also be constructed for the southern hemisphere.

54. The Commission recommends that all the meteorological services of the world augment their observations during the Polar Year, especially at the hours 0^h or 12^h G. M. T., so that there may be sufficient data to establish world synoptic maps for these hours.

55. The Commission recommends that meteorological services augment observations on ships during the Polar Year, pointing out especially the importance of auroral observations.

56. The Commission recommends that the revised memorandum of Mr. Simpson serve as a basis for the instrumental equipment of polar meteorological stations.

57. The Commission recommends that, if possible, all the polar meteorological stations send out by radio four times daily their observations according to the usual code employing, in cases where the emission is by short waves, a station sufficiently strong as an intermediary transmitting station.

Action Taken by the International Meteorological Committee at Its Meeting at Locarno, Switzerland, October 8, 1931, Regarding the Polar Year

Subsequent to the Innsbruck meeting of the International Commission for the Polar Year 1932-33, the International Meteorological Committee at its Locarno meeting October 8 adopted unanimously the following resolution:

"The Committee regrets greatly that the financial crisis of the world will doubtless diminish the participation of the Polar Year.

"Seeing that the work already assured will procure a body of observations of great importance to geophysics and its practical applications, that the interruption of preparations in certain countries constitute a certain loss, and that a sufficiently great uncertainty exists as regards the success of the Polar Year after a delay of some years, the Committee approves the work of the Commission for the Polar Year 1932-33 and recommends that the Commission obtain all the support possible for executing the enterprize of the Polar Year."

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SUMMARY OF THE YEAR'S WORK, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON[1]

By J. A. Fleming

The year July 1, 1930, to June 30, 1931, was devoted largely to developing undertakings already inaugurated and to the reduction and discussion of accumulated observational material rather than to the launching of new enterprises and extensive acquirement of new data. Accordingly, effort was concentrated on the discussion and preparation for publication of a large amount of material already accumulated in the magnetic survey and at the observatories in Peru and Western Australia and in beginning interpretation of the results. Excellent progress was also made in compiling the vast material pertaining to oceanology, biology, and meteorology secured on Cruise VII of the *Carnegie*, to the end that the first volume presenting the physical oceanographic results may be issued in 1932.

The year was also marked by the active participation of the staff in aiding formulation of plans for one of the greatest international projects for the acquirement of geophysical data yet attempted—the Jubilee International Polar Year proposed in 1932-33. Data in terrestrial magnetism and electricity are sorely needed in the polar regions, where extreme conditions in the variations of the natural phenomena exist, in order to provide more reliable material in the large areas above 60° north and south latitude for extension of the Gaussian harmonic analyses which have heretofore been practically limited to the region between latitude 60° north and 60° south because of the paucity of polar data.

The interpretation of accumulated data and the study of magnetic correlations with other geophysical, solar, and cosmic phenomena received great impetus through the generosity of the Prussian Ministry in making possible the residence, as research associate of the Institution for one year from April 1, 1931, in Washington with the Department, of Dr. J. Bartels, a German authority on terrestrial magnetism and electricity, to supplement and to counsel on discussions already under way by members of the staff.

Complete magnetic records and tabulations derived from observations at Watheroo, Western Australia, during the twelve years 1919-1930 are now available. For all theoretical investigations, this Observatory, because of the isolated position in the southern hemisphere, is the only source of our knowledge about the magnetic conditions over a large part of the globe, so that an ample discussion is urgent. Apart from the ordinary computation and harmonic analysis of the solar diurnal variation on all days and on international quiet days, two special reductions were initiated. The study of stereographic projections was taken up as a means of more effectively interpreting and demonstrating terrestrial-magnetic phenomena.

[1]Extracted from the annual report in Year Book No. 30 of the Carnegie Institution of Washington for the year July 1, 1930, to June 30, 1931, to which reference should be made for more detailed account of field, observatory, instrumental, and laboratory work, and of publications.

The investigation of correlation of the initial impulses of magnetic storms is progressing. Some twenty foreign observatories have generously cooperated by sending photographic reproductions of magnetograms showing the storms of January 29 and March 29, 1924; September 21, 1925; March 5, 1926; January 24 and May 27, 1927; and October 18, 1928. These, with magnetograms of five observatories kindly loaned by the United States Coast and Geodetic Survey and those of Watheroo and Huancayo, make a total of 27 observatories more widely distributed over the world than has been possible heretofore. In connection with this investigation, an apparatus has been designed to reproduce photographically magnetograms to one common scale, thus effecting a large saving of time required in laborious compilation of data.

The manuscript giving results of the research on the effects of pressure on the critical temperature of magnetization of iron and other ferromagnetic materials done in cooperation by the Geophysical Laboratory and the Department was completed and accepted for publication in the Philosophical Magazine.

The investigations in atmospheric electricity were materially forwarded during the year by compilations and reductions of accumulated data, by further critical study of the action of Aitken nuclei, and by the designing and testing of a large-ion counter for use in the study of the factors and laws determining ionic balance in the atmosphere and its relation to atmospheric pollution. The discussion of earth-current data at Watheroo, Huancayo, and Tucson show very close correlation between magnetic and earth-current disturbances.

The magnetic, atmospheric-electric, earth-current, and meteorological programs at the Watheroo and Huancayo observatories, the atmospheric-electric program in the Deck-Observatory at Washington, and the cooperative work in atmospheric electricity with the Apia Observatory of the Department of Scientific and Industrial Research of New Zealand and at the Tucson Observatory of the United States Coast and Geodetic Survey were maintained. At Tucson, earth-current apparatus was installed in cooperation with the United States Coast and Geodetic Survey, the Mountain States Telephone and Telegraph Company, and the American Telephone and Telegraph Company. In order to obtain data on solar correlations, arrangements were completed with the Mount Wilson Observatory for the loan and installation of spectrohelioscopes at the Huancayo and Watheroo observatories. In cooperation with the Institution's Advisory Committee in Seismology, arrangements were also made to place a seismological observatory at Huancayo, thus providing essential data from a station to the south of the five stations operated by the United States Coast and Geodetic Survey and of the stations planned for the Canal Zone.. Provision was made to install radio equipment at Huancayo. In view of the correlation of terrestrial-magnetic phenomena with movements of the Kennelly-Heaviside layer, construction has been begun of apparatus for automatically recording variations in the height of the layer; it is hoped that the installations may be completed at both observatories in 1932.

The artificial production of beta- and gamma-rays of energies equivalent to most of those emitted by radioactive substances, using equipment developed at the Department during past years, was demonstrated by measurements. Other measurements showed the production of large

numbers of high-speed protons (hydrogen nuclei) of energy-equivalents up to 800,000 volts. Refinements were developed making possible the continuous operation of Tesla coils and tubes at peak-voltages of 1,500,000 or more, and a study of nuclear collisions and a search for possible nuclear (atomic) disintegration using protons of these energies is under way. Looking toward the ultimate extension of the work to super-radioactive energies, an impulse-generator method utilizing concentric Faraday cages, theoretically unlimited as to the voltages attainable, was devised and preliminary tests were made.

The importance of these researches is evidenced by the award made by the American Association for the Advancement of Science of its eighth annual prize to Tuve, Hafstad, and Dahl for the paper presented by them at the Cleveland meeting in 1930 on "Experiments with high-voltage tubes."

Experiments were continued using multiple coincidences of Geiger-Müller tube-counters for studies of the penetrating-radiation. There is no doubt that this method provides a powerful tool for investigating the real nature of "cosmic rays" and their properties.

The reductions and compilations of the work in physical and chemical oceanography from observations made aboard the *Carnegie* were continued throughout the year. The bottom-samples and the biological samples were prepared for distribution to various specialists for report. As in the preceding year, this work has been greatly forwarded by the active and generous cooperation of many organizations and individuals.

Important instrumental advances were made for magnetic and electric determinations. Improvements are being devised for the marine collimating-compass, having in mind the reduction of dynamic deviations so troublesome in any observations at sea. The design of a submerged, non-magnetic ocean-magnetograph which may be towed from any ship for recording the magnetic elements is in development. Improved apparatus for the experimental investigation of dynamic deviations is now completed and ready for use.

The problems in terrestrial magnetism and electricty and in atomic physics are so complex that coordinated effort is essential to effect any real headway. To forward such coordination two members of the staff spent some time in Europe attending the Fourth General Assembly of the International Union of Geodesy and Geophysics at Stockholm in August 1930; during August and September many organizations and individuals carrying on research in the Department's fields in Germany, France, Finland, U. S. S. R., and England were visited and through numerous personal contacts means of effecting coordination and cooperation were discussed. A third member of the staff spent two months in Europe studying experimental investigations on high-voltage and allied problems and discussing various aspects of our own work, and another spent June on the west coast in similar studies and discussions.

The Department's policy of cooperating with other investigators and organizations interested in its geophysical researches was maintained. This was particularly the case in endeavors to increase the magnetic secular-variation material so urgently required, not only for advances in terrestrial magnetic theory but in increasing importance in the application of geophysical methods to the investigations of the Earth's crust to great depths.

The theoretical investigations during the year were in large measure in continuation of those noted in last year's summary and are given below.

Solar activity and secular variation—Fisk's study of relations between solar activity and secular variation was extended to include data to date. The results confirm the apparent lag between solar activity, indicated by sunspot-numbers, and magnetic activity, indicated by the mean magnetic character-numbers, shown by the previous discussions. The difference between annual changes derived from all-day means and selected-day means for the Cheltenham data showed that this difference fluctuates in agreement with sunspot-numbers, and it is significant that the same sort of lag exists here as is indicated by comparison with magnetic character-numbers.

The gradual accumulation of reliable data from various parts of the Earth, notably from the magnetic observatories, permits a progressive refinement of the charts showing the distribution of the rates of secular variation. The period covered by the records of many of the existing observatories has now become sufficient to permit a comparative study of the fluctuations in secular rate with more detail than has been practicable hitherto. These fluctuations, particularly in the case of the horizontal component, are found by the analysis made by Fisk to follow closely the sunspot-cycle, as was expected, due to the after-effects of magnetic storms, but interesting variations of amplitude with geographical region were revealed. Such fluctuations are of a magnitude sufficient to modify very considerably the apparent secular change determined from observations at single stations in the field and must be taken into consideration in the most accurate determinations. A condensed account of the results of this investigation for horizontal intensity was prepared for the third report of the Committee to Further the Study of Solar and Terrestrial Relationships of the International Research Council.

Bartels prepared an outline on the reduction of the Watheroo magnetic data for lunar variations, which it is expected may be completed within the next two years. This is planned to give the most detailed information on the lunar variation but will limit the subdivision of the material so that (1) the amount of data used in each group will be large enough to reduce accidental variation in the average, (2) arithmetical work will be cut down without risking accuracy, (3) the average solar variation will be obtained for each group, (4) continuation of the computation for data accumulated in future years may be easily added, and (5) comparison with similar work done for other organizations will be readily possible. The outstanding theoretical interest in this work is the remarkable difference in the changes of solar and lunar variations with respect to magnetic activity and sunspot-cycle, lunar variations being affected more by magnetic activity of the particular day but very slightly by sunspot-cycle, which clearly affects the solar variation. Therefore, the data are being grouped according to (1) season, (2) final relative sunspot-numbers, and (3) magnetic activity.

Magnetic activity—Measures of activity derived from the sum of changes of ordinates by the ordinate-integrator were further compared by Duvall with other measures and resulting correlation-coefficients determined. While actual numerical work on this measure was not com-

pleted beyond a single month, the results indicate that a high degree of similarity at the different observatories may be expected. It is hoped by theoretical considerations one may be able to find relations between ordinate-change measures for observatories in greatly differing geographic locations. Following the resolution adopted by the Association of Terrestrial Magnetism and Electricty of the International Union of Geodesy and Geophysics at Stockholm in August 1930, Duvall began the compilation of the measure of activity proposed which involves the extreme ranges in horizontal and vertical intensity, namely, $(HR_H+ZR_Z)/10{,}000$, for the Huancayo and Watheroo observatories beginning with 1929.

Magnetic storms—Progress was made by Peters in the scalings and computations of the initial impulses of seven magnetic storms, as recorded on the magnetograms of 27 observatories. The United States Coast and Geodetic Survey and some 20 foreign observatories have assisted in this investigation by sending copies or loaning original magnetograms. Because of the addition of several new observatories, the data thus available are more widely distributed over the Earth than has been possible heretofore.

In the latest studies by Wallis of the arctic data obtained during the MacMillan expeditions of 1921-22 and 1923-24 in connection with results at selected observatories elsewhere, the principal aim has been to locate the sources of magnetic disturbances. Several sudden changes in the Earth's magnetic field, which appeared to be simultaneous over the Earth's surface, were selected. The projections of the total-intensity disturbance-vectors were plotted on the meridian-planes and on the plane of the equator. It was found that the meridian-plane projections, with one or two exceptions perhaps, all pointed in one general direction, either toward or away from the polar regions. The equator-projections showed a tendency to point either toward or away from the magnetic axis of the Earth. However, in both projections there were occasional exceptions to the rule in the case of individual stations. The material leads to the impression that the disturbances may be caused by electric currents circulating around the Earth in the region of the auroral zone.

Arctic magnetic charts—The interest in polar research and exploration, created in part by the proposed International Jubilee Polar Year, made it desirable to prepare magnetic charts of the Arctic Ocean and surrounding land areas compiled from the latest available observations. Fisk prepared such charts for declination, inclination, horizontal intensity, and total intensity, and a chart showing magnetic meridians, utilizing the compilations of data maintained by Peters, including available data obtained by more recent expeditions. On the charts the unsymmetrical distribution of the intensity-components with respect to the magnetic north pole was an especially noteworthy feature. Of practical importance is the fact that the area of feeble horizontal intensity (the force upon which the satisfactory functioning of the compass depends) extends in a long band from the northern part of Canada across the Arctic basin to the most northern land of Siberia at Lenin Land north of Cape Chelyuskin. The charts will serve as a working basis for the study of secular change within that area when the data expected from the completion of the proposed Polar Year campaign become available.

Magnetic work at sea and dynamic-deviation investigation—Consider-

able time was given by Fleming, Peters, and Soule to possible solution of the problem of making magnetic observations at sea in cooperation with expeditions or organizations employing vessels or proposing to build vessels of ordinary construction. In this connection, improvements were suggested for reducing the motion of the magnet-system and improving the optical arrangements of the marine collimating-compass. The possibilities of securing automatic registration of magnetic elements below the surface or in the air away from the ship were given much study, but a practical solution is yet to be reached.

The automatic swing for recording photographically experiments on ship-deviations is in the final stages of completion and is being set up in the Standardizing Magnetic Observatory at Washington. The details of this apparatus were devised by Huff according to the requirements suggested by Peters' earlier experiments and further theoretical considerations.

Photographic method of changing the ratio of ordinate-scale to abscissa-scale—Peters and Green developed a photographic method for the purpose of reproducing magnetograms or other continuous photographic records made at different observatories on the same scales as regards both time and value of magnetic or other recorded element with all the minutiæ of detail. In making photographic exposures of the photographic record and the resulting negative, the sensitized paper is inclined at predetermined angles depending upon the modifications required of the abscissæ and ordinates, respectively, and upon the condition that the respective scales be uniform throughout the final positive. While there is no limit theoretically to the choice of ratio desired between the scale of ordinate and the scale of abscissa, the limit is fixed in practice by the depth of focus available, and the smallest stop usable, or by the number of repetitions of the operation of two exposures. Actual tests and photographic prints were made, using an experimental set-up in which the final ordinates were made about three times as long as the original with respect to the abscissæ in one operation of two exposures and which fully demonstrate the feasibility of the method. Final designs were completed for this apparatus and it is in construction.

Atmospheric pollution—It has been well established that the presence of nuclei affects the number of large and small ions in the atmosphere, and consequently the value of the atmospheric conductivity. The potential gradient is in turn affected by the altered conductivity, but is also affected by the presence of space-charge which results from a preponderance of large and small ions of given sign. There is thus an intimate relation between the atmospheric-electric elements and atmospheric pollution. An investigation was undertaken by Wait and Torreson to examine the relationships existing between large ions, small ions, and condensation-nuclei and to determine the character of the nuclei. A large-ion counter was completed and is being used simultaneously with a small-ion counter and a condensation-nuclei counter.

Publications—The first of a contemplated series of manuscripts giving detailed descriptions of the Department's specially designed apparatus required in its research fields was completed by Torreson. This describes in detail the standard observatory-type of conductivity-apparatus; it discusses the theory and the construction, installation, adjustment, and operation of the instrument, with notes on the interpre-

tation of records obtained with it. A second manuscript is in preparation by Gish on the earth-resistivity apparatus developed after his design and so successfully used in the field since 1924.

Abstracts of published material and of investigations not yet published are given in a special section of the report.

Research associates—Dr. J. Bartels, with the permission of the Prussian Ministry, was allowed leave for one year from April 1, 1931, from his chair of physics at the Forsthochschule in Eberswalde, Germany, and his duties as Privatdozent in Geophysics at the University of Berlin, that he might be in residence at Washington as a research associate of the Institution with the Department. Research Associate H. U. Sverdrup continued at Washington until August, and after his return to Bergen continued his connection through the report-year. G. Breit, A. E. Kennelly, and Greenleaf W. Pickard continued as research associates throughout the report-year. Grateful acknowledgement is made to these five men for their constructive suggestions and for material collaboration they have extended in the investigations and interpretation of data.

Dr. Harry M. W. Edmonds, magnetician on the staff since 1910, was retired on half-pay December 31, 1930. He was intimately associated during his long service with the four major activities of the Department. For a number of years he was on the *Carnegie* and was in command of her fifth cruise; in 1913 he accomplished a hazardous magnetic expedition into the Hudson Bay region; in 1919 he took charge of the construction of the Huancayo Magnetic Observatory; in 1921 while assisting in the reorganization of the magnetic and atmospheric-electric program of the Apia Observatory, he supervised the extension of the magnetic survey in the Pacific islands. Since 1922 he was engaged at the office in making final reductions of the first ten years' results obtained at the Watheroo Magnetic Observatory. The Institution may well be proud of his distinguished service to terrestrial-magnetic science in this Department.

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(See also pages 310 and 317)

Köppen, W., und R. Geiger: *Handbuch der Klimatologie.* Band I, Teil A. *Mathematische Klimalehre und astronomische Theorie der Klimaschwankungen,* von M. Milankovitch; Teil D. *Mikroklima und Pflanzenklima,* von R. Geiger; Teil F. *Klimatologie der freien Atmosphäre,* von A. Wagner. Berlin, Gebrüder Borntraeger, 1930-1931 (IV+176+46+70). 26 cm.

The "Mathematical Climatology" of Milankovitch is a thorough study of the geometrical and astronomical aspects of solar radiation as received on the Earth. The physical properties of the Sun's radiation are throughout the book assumed to be constant. The first chapter deals with the solar radiation which would reach the Earth if the atmosphere were absent. Formulas and tables are given for the daily and annual variations of radiation in different latitudes, instantaneous values as well as averages for seasons and other intervals. The secular changes in radiation are expressed in terms of the astronomical elements, which determine the position of the Earth's orbit and rotation-axis with respect to the Sun, that is, longitude of the perihelion, eccentricity, and obliquity of the ecliptic. Numerical values for these three elements are given in the third chapter for the last 600,000 years on the basis of Leverrier's theory; the corresponding sums of the radiation for winter and summer are computed and compared with the different phases of the ice-age.

In the second chapter, on the influence of the Earth's atmosphere on the radiation, and the relation between radiation and temperature, water-vapor is still regarded as a grey radiator; so this part of the book can no longer be regarded as an account of the present state of our knowledge. Here the author, used to the numerical exactness of astronomical data, overrates continuously the reliability and representative value of geophysical data; for instance, when he calculates the occurrence of maxima in the diurnal temperature-variation of air to less than one-tenth of a second. But this does not affect the lasting value of the book which is contained in the astronomical part. Outside the atmosphere, ionizing solar wave-radiation must be distributed over the Earth in the same way as the total radiation; this lends new interest to the well-known fact that the poles, on a summer day, receive more radiation than the equator.

The part on microclimate and plant climate by R. Geiger is a good and comprehensible account of a chapter of applied climatology, which owes valuable contributions to the researches of the author. The part on climatology of the free atmosphere by A. Wagner collects and discusses the results of aerological observations on temperature, humidity, and wind all over the world. J. Bartels

LES ÉLÉMENTS DU MAGNÉTISME TERRESTRE À JASSY EN 1931

PAR ST. PROCOPIU

Déterminations magnétiques en Roumanie—Les éléments du magnétisme terrestre, déclinaison, inclinaison et composante horizontale, n'ont été que trés rarement déterminés en Roumanie. Ainsi, on connaît une détermination de déclinaision à Bucarest, faite en 1772, qui a donné la valeur 11° 36′ W, et une série de déterminations, toujours de la déclinaison, pour 28 localités des pays roumains, effectuées entre 1828 et 1832 par les officiers de l'état majeur russe, à l'occasion de la guerre russo-turque, en vue d'un levé de carte des pays roumains. On a trouvé à cette date (1828) pour Bucarest, $D = 11°\ 14'$ W, et pour Jassy, $D = 11°\ 52'$ W. Des calculs, postérieurs à cette date, faits par Hepites, ont indiqué que la déclinaison à Bucarest a passé aux environs de l'an 1798 par un maximum ($D = 13°\ 50'$ W) et que, depuis lors, la déclinaison diminue continuellement.

Des observations systématiques et pour les trois éléments du magnétisme terrestre n'ont été effectuées qu'en 1858, par Kreil[1], alors directeur de l'Observatoire météorologique de Vienne, et en 1898 à 1901 par St. Hepites et J. Murat[2], directeurs de l'Observatoire météorologique de Bucarest. Kreil a donné les valeurs des éléments du magnétisme pour cinq localités des pays roumains (Calafat, Bucarest, Galatz, Sulina, et Île des Serpents). Pour Bucarest, en 1858, les valeurs sont: $D = 7°\ 55'.4$ W, $I = 59°\ 51'.5$ N, $H = 0.22638$. Hepites et Murat ont fait une détermination complête pour 72 localités de l'ancien Royaume. Voici les valeurs qu' ils ont trouvées à cette date pour Bucarest et Jassy:

		D	I	H
Bucarest	(juillet 1898)	4° 31′.8 W	58° 51′.1 N	0.23302
Jassy	(août 1898)	3° 38′.2 W	60° 53′.8 N	0.22259

Les valeurs déterminées précédement par Kreil leur ont servi á déduire les variations séculaires en Roumanie. Ils ont adopté d'après leurs calculs, les valeurs moyennes suivantes: $dD = -5'.1$, $dI = -1'.5$, $dH = +0.00017$. À l'aide de ces valeurs des variations séculaires ils ont calculé les éléments magnétiques pour 1906. Mais il n'est pas certain que ces valeurs calculées correspondent aux valeurs réelles, par suite du fait que dans ces régions, l'inclinaison et la composante horizontale ont changé leur sens de variation aux environs de l'an 1900. En effet, on connaît, d'aprés les déterminations de l'Observatoire de Potsdam (long. 13°.1 E, lat. 52°.4 N), que la composante horizontale qui augmentait et l'inclinaison qui diminuait avant 1900, ont changé leur sens de variation depuis 1905 ou 1906. Ce changement s'est produit avant 1900 pour les régions à l'est de Potsdam[3]. De sorte que les signes de dI et dH doivent être changés, si on admet que le changement de variation de

[1]Magnetische und geographische Ortsbestimmungen im sudöstlichen Europa. Wien, SitzBer. Ak. Wiss., 36 (1859).

[2]Contributiuni la fizica globului vii. Hartile magnetice ale Romaniei la 1 Januar 1906. Ann. Acad. Româna Ser. 2, 30 (1907).

[3]A. Nippoldt, Erdmagnetismus. Müller-Pouillet, Handbuch de Physik, Bd. 4, Buch 5, p. 1358 (1914).

l'inclinaison et de la composante horizontale a eu lieu, pour les pays roumains, vers 1900 ou avant cette date.

Jassy, région d'anomalie magnétique—Aucune perturbation n'a pu être constatée par Hepites, en effectuant le levé magnétique de la Roumanie et surtout il en a conclu[4] que la perturbation déjà constatée par Kreil dans la région d' Odessa ne s'étend pas jusqu' à l' Île des Serpents et les bouches du Danube. Mais si on regarde de plus près les valeurs des élements magnétiques de 1898, on constate que, en dehors de quelques faibles anomalies en Dobrogea, il faut considérer une plus forte anomalie magnétique sur une ligne qui unit Rediu (long. 27° 14′ E, lat. 47° 34′ N) à Jassy (long. 27° 29′ E, lat. 47° 10′ N) et qui se continue jusqu' à Dorohoiu (long. 26° 25′ E, lat. 47° 59′ N). La déclinaison, en 1898, a les valeurs suivantes: 3° 32′ W à Dorohoiu, 3° 52′ W à Rediu, et 3° 38′ W à Jassy, tandis que des localités à l'ouest de cette ligne possèdent des valeurs plus faibles. Par exemple, Tg.-Frumos, à 40 km vers l'ouest de Jassy, a une déclinaison de 3° W, et Vaslui et Barlad sur le même méridien que Jassy ont des déclinaisons 3° 07′ et 3° 11′ W. Une autre constatation est qu' Odessa, à la même époque, avait la déclinaison de 4° 41′ W[5] tandis que dans une région, plus bas, l'Île des Serpents avait une déclinaison de 2° 08′ W.

Une conclusion qui s'impose est que Jassy possède une anomalie magnétique. Cette anomalie pourrait être locale ou bien elle tient une région plus étendue comprenant Kichineu, Tighina, c'est-à-dire le *plateau moldo-bessarabien*, et peut-être Odessa. Les mesures que nous avons entreprises autour de Jassy et dans la région bessarabienne vont nous permettre de décider quelle est l'étendue de cette anomalie magnétique.

Mesures à Jassy en 1931, effectuées par St. Procopiu et Gh. Vasiliu—Nous nous sommes proposé de reprendre la détermination des éléments du magnétisme en Roumanie pour plusieurs localités de l'ancien royaume et des nouvelles provinces, de calculer les variations séculaires, et d'étudier de plus près les régions d'anomalie magnétique, s'il y en a. A ce but notre Laboratoire s'est procuré un théodolite-magnétomètre de la Maison Chasselon, Paris, type moyen, No. 156, avec lequel nous avons déterminé la déclinaison et la composante horizontale, et une boussole d'inclinaison, ancien système Sécrétan. Les mesures ont été effectuées dans le jardin Adamachi, Jassy-Copou, à 1.5 km de la ligne de tramway, pendant les mois de mai, juin, et juillet 1931. Les résultats de ces mesures sont les suivants:

Date	Heure	*D*	Date	Heure	*H*	Date	Heure	*I*
1931		′ ″	1931			1931		° ′
18 mai	15	22 14 E	18 mai	18	0.21417	2 juin	16	62 01
18 juin	10	22 09 E	17 juin	10	0.21421	2 juin	18	62 10
4 juil	10 et 11	23 30 E	18 juin	11	0.21428			
13 juil	9 et 10	25 14 E	4 juil	11	0.21464			
			13 juil	9 et 11	0.21462			

[4]Levé magnétique de la Roumanie. Congrès Internat. Météorologie, Paris, 1900.

[5]Calculée d'après les données trouvées dans J. A. Fleming, Rep. and Comm., Stockholm Assembly, Internat. Geod. Geophys. Union, Sect. Terr. Mag. Electr., Dep. Terr. Mag., Carnegie Inst., Washington, D. C., p. 41 (1930).

On calcule, comme moyennes, pour les mois de mai, juin, et juillet 1931, les valeurs suivantes à Jassy: $D=0° 23' 17''$ E; $H=0.21438$; $I=62° 05'$ N.

Variations séculaires—Les valeurs des éléments du magnétisme terrestre à Jassy déterminées par nous (Procopiu et Gheorghiu) en 1931, peuvent être comparées aux valeurs des mêmes éléments, déterminées en 1898 par Hepites et Murat, et indiquées au début de cet article. De la comparaison des deux séries de déterminations, à 33 ans d'intervalle, il résulte les variations séculaires suivantes: $dD=-7'.3$; $dH=-0.00025$; $dI=+2'.1$. Ces variations séculaires sont en accord avec celles indiquées sur les cartes de l'Amirauté anglaise pour 1922[5] (on y lit $dD=-8'$, $dH=-0.00003$, et $dI=+2'$ à $3'$) mais non pas avec les valeurs calculées par Hepites et Murat. L'explication de ce désaccord tient dans les changements de variation de l'inclinaison et de la composante horizontale, intervenus vers 1900, et dequels les auteurs cités ne se sont rendu compte par des mesures directes à cette date.

Il résulte que la déclinaison magnétique (occidentale à Jassy) qui a diminué depuis 1828 (et peut-être depuis 1800) jusqu' et 1898, a continué de diminuer à raison de 5′ à 7′ par an, et en 1928 elle s'est annulée. *I epuis 1928 la déclinaison est devenue orientale à Jassy et augmente d'environ 7′ par an.* L'inclinaison magnétique augmente continuellement depuis 1898, ou une époque voisine, à raison de +2′ par an, tandis que la composante horizontale diminue continuellement depuis la même époque. Ces variations ressemblent à celles déterminées à Odessa en 1900, 1910, et 1925[6].

Avec ces remarques on a les variations séculaires suivantes pour Jassy depuis 1928, lorsque la déclinaison est passée par zéro: $dD=+7'.3$; $dH=-0.00025$; $dI=+2'.1$.

[6] G. Angenheister, Handbuch der Physik, **14** (1927).

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WALLACE MORRELL HILL

By D. L. Hazard

Wallace Morrell Hill, magnetic observer in the U. S. Coast and Geodetic Survey for many years, died on October 18, 1931.

Mr. Hill was born at Elizabeth, N. J., on June 28, 1868. He received the degree of M.E. from Stevens Institute in 1889, and after several years devoted to teaching and writing on topics related to electrical and mechanical engineering, he entered the Coast and Geodetic Survey as a magnetic observer on March 10, 1904.

He took an active part in the magnetic survey of the United States then in progress and in the next ten years made magnetic observations in practically every state in the union. In later years much of his time was devoted to observations at repeat-stations all over the United States for the determination of the change of the Earth's magnetism with lapse of time.

In 1912 and 1913 he made a magnetic survey of the Philippine Islands, which involved considerable danger and hardship because of difficulties of transportation prevailing at that time. In 1924 and 1925 he made repeat-observations at a considerable number of stations in those islands.

He was in charge of the magnetic observatory at Vieques, Porto Rico, from 1918 to 1921 and of the observatory near San Juan, Porto Rico, from 1926 to 1928. During the latter assignment he suffered an attack of spru and although he apparently recovered from its effects, he had recurrences of the trouble in later years, leading finally to the condition which caused his death. From May, 1923, to August, 1924, he was in charge of the magnetic observatory near Honolulu, Hawaii.

For short periods between his various field assignments he was on duty in the Washington office, assisting in the computation of the field and observatory results.

During these many years Mr. Hill devoted himself whole-heartedly to the proper, execution of every piece of work to which he was assigned and the results bear witness to the success of his efforts.

United States Coast and Geodetic Survey,
Washington, D. C.

CORRECTION-FACTORS AND CORRECTED DAILY MEANS OF THE SOLAR INDICES AS GIVEN IN THE INTERNATIONAL ASTRONOMICAL BULLETINS, 1930

By Howell C. Brown

The figures for 1930 were obtained by the same method of averaging as outlined in the Journal for December 1930 (pp. 237-244) with the single difference, that the addition of Coimbra to cooperating observatories makes one more correction-factor. No other changes have been made and it is hoped that this continuation of the corrected daily means will be of use to other workers in the field of terrestrial and solar relationships.

Table 1—*Correction-factors of solar indices, 1930*

Station	No. obs.	Jan.-Mar.	No. obs.	Apr.-June	No. obs.	Jul.-Sep.	No. obs.	Oct.-Dec.	No. obs.	Jan.-June	No. obs.	Jul.-Dec.
					Calcium flocculi—Whole disc							
Arcetri	....	....	....	....	....	....	....	....	....	....	....	....
Coimbra	....	....	....	....	34	1.69	9	2.04	....	....	....	....
Ewhurst	....	....	....	....	....	....	....	....	....	....	....	....
Meudon	17	1.09	29	1.06	44	1.08	15	0.99	....	....	....	....
Mt. Wilson	17	1.06	29	1.08	44	1.33	15	1.29	....	....	....	....
Kodaikanal	17	0.82	29	0.78	44	0.80	15	0.78	....	....	....	....
Tokyo	15	0.98	13	0.96	24	0.85	18	0.89	....	....	....	....
Del Ebro	17	1.19	29	1.13	44	0.96	15	1.08	....	....	....	....
					Calcium flocculi—Central disc							
Coimbra	....	....	....	....	34	1.72	9	1.66	....	....	....	....
Meudon	17	1.02	29	1.01	44	0.90	15	0.85	....	....	....	....
Mt. Wilson	17	0.76	29	0.87	44	1.02	15	0.88	....	....	....	....
Kodaikanal	17	0.98	29	1.11	44	1.19	15	1.15	....	....	....	....
Tokyo	15	0.83	15	0.75	24	0.79	18	1.02	....	....	....	....
Del Ebro	17	1.26	29	1.06	44	0.99	15	1.06	....	....	....	....
					Bright *Hα*—Whole disc							
Arcetri	....	....	....	....	....	....	....	....	13	1.17	13	1.34
Ewhurst	....	....	....	....	....	....	....	....	19	1.21	13	0.90
Meudon	24	1.04	42	1.03	37	0.99	22	1.20	....	....	....	....
Mt. Wilson	24	0.82	42	0.87	37	0.89	22	0.87	....	....	....	....
Kodaikanal	24	1.21	42	1.12	37	1.09	22	0.98	....	....	....	....
					Bright *Hα*—Central disc							
Arcetri	....	....	....	....	....	....	....	....	13	1.26	13	1.86
Ewhurst	....	....	....	....	....	....	....	....	19	1.59	13	1.08
Meudon	24	1.22	42	1.03	37	0.81	22	1.16	....	....	....	....
Mt. Wilson	24	0.70	42	0.76	37	0.55	22	0.78	....	....	....	....
Kodaikanal	24	1.22	42	1.46	37	1.00	22	1.21	....	....	....	....
					Dark *Hα*—Whole disk							
Arcetri	....	....	....	....	....	....	....	....	13	1.50	10	2.12
Ewhurst	....	....	....	....	....	....	....	....	18	1.06	12	0.97
Meudon	25	1.12	42	0.94	37	0.97	21	1.51	....	....	....	....
Mt. Wilson	25	1.10	42	1.24	37	1.11	21	0.82	....	....	....	....
Kodaikanal	25	0.81	42	0.93	37	0.94	21	0.89	....	....	....	....
					Dark *Hα*—Central disc							
Arcetri	....	....	....	....	....	....	....	....	13	1.78	10	1.96
Ewhurst	....	....	....	....	....	....	....	....	18	1.19	12	1.11
Meudon	25	1.52	42	1.19	37	1.19	21	1.82	....	....	....	....
Mt. Wilson	25	0.88	42	0.87	37	0.92	21	0.95	....	....	....	....
Kodaikanal	25	0.81	42	0.98	37	0.90	21	0.73	....	....	....	....

TABLE 2—*Corrected daily means of solar indices, 1930*

Day	Bright H_α—Whole disc												Bright H_α—Central disc											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	2.5	1.4	2.3	2.0	2.2	1.1	1.0	1.4	2.3	2.0	2.3	1.7	1.3	0.7	2.7	2.2	1.8	0.8	1.4	1.1	1.9	2.4	0.4	1.6
2	1.3	2.0	2.4	2.2	2.2	0.8	1.6	1.2	2.2	1.6	2.3	1.3	0.6	1.3	2.4	2.2	2.2	0.0	1.3	0.2	1.9	2.2	0.0	1.2
3	1.7	2.2	3.1	2.7	2.2	1.3	1.7	0.9	1.9	1.6	2.1	0.9	0.4	1.2	1.4	2.4	1.7	0.5	1.3	0.6	0.7	2.0	0.0	1.2
4	1.8	3.1	2.8	2.0	1.8	1.0	1.4	0.7	2.9	1.8	1.3	1.0	0.0	1.9	0.0	1.3	0.8	0.6	1.3	0.6	1.6	1.2	1.0	0.7
5	.....	3.4	2.8	1.9	2.6	1.2	1.6	0.2	3.5	1.8	1.7	0.6	.....	3.2	1.2	0.8	1.2	1.4	0.6	0.2	2.6	0.4	1.6	0.3
6	1.2	3.4	3.0	1.6	2.1	1.1	1.7	0.8	2.8	2.0	1.2	1.0	0.7	3.5	3.4	1.0	2.1	1.5	1.3	0.4	1.6	0.4	1.5	0.4
7	1.8	4.2	2.4	1.8	2.1	1.6	1.0	1.0	2.8	1.8	1.3	0.5	0.6	3.4	3.7	1.9	2.1	1.7	1.2	0.0	1.8	0.4	1.9	0.0
8	2.5	4.0	2.4	2.6	1.1	1.2	1.0	1.2	2.8	2.0	1.7	0.0	2.1	4.4	2.8	2.8	1.8	1.4	1.8	0.0	1.6	0.0	1.6	0.0
9	3.1	2.6	2.8	2.8	1.1	1.4	1.3	1.0	2.7	.....	2.0	0.0	3.7	3.2	3.6	2.2	0.0	1.5	1.2	0.3	2.2	.....	1.2	0.0
10	3.6	2.7	2.4	2.0	0.9	1.6	0.8	1.2	2.3	2.2	1.5	0.6	3.2	2.3	0.8	0.6	0.8	1.7	0.0	1.0	1.7	3.0	1.3	0.0
11	3.0	2.4	2.3	2.3	1.0	1.6	1.0	1.0	2.4	.....	0.8	1.0	3.4	1.6	0.2	2.0	0.8	1.7	0.0	1.0	1.3	.....	0.8	0.0
12	4.8	1.9	1.9	2.0	1.0	1.6	1.0	1.0	1.8	2.2	0.6	1.4	3.7	0.9	0.5	2.0	0.8	2.2	0.2	1.7	1.4	2.1	0.3	0.0
13	3.4	1.7	1.5	2.2	1.0	1.9	1.0	1.0	2.0	2.7	0.5	1.0	3.9	1.0	0.2	1.8	0.8	1.9	0.8	1.0	1.2	1.3	0.0	0.2
14	4.8	2.0	1.6	2.0	1.0	1.0	0.8	1.0	1.5	2.6	0.7	1.4	3.7	1.5	0.0	1.5	1.2	0.8	0.7	0.7	0.3	1.3	0.4	1.6
15	.....	1.9	1.2	1.6	1.1	1.4	1.0	1.0	1.9	1.8	1.0	1.4	.....	0.9	0.0	1.3	0.5	0.0	1.0	0.0	0.8	1.6	0.0	2.0
16	3.0	1.2	1.1	1.4	0.8	1.4	1.0	0.8	1.5	2.0	1.0	1.4	1.4	0.2	1.8	0.4	0.8	0.4	1.0	0.0	0.5	1.8	0.0	2.0
17	2.6	1.6	1.2	1.4	1.0	1.0	1.0	0.6	1.2	1.3	1.0	0.8	3.1	0.3	1.2	0.3	0.5	0.4	1.0	0.0	0.0	0.8	0.8	0.6
18	2.6	1.4	2.2	1.0	1.3	0.9	1.0	0.2	1.1	1.1	1.0	1.4	2.8	1.3	3.0	0.0	0.0	1.5	0.4	0.0	1.0	0.3	2.1	0.4
19	3.4	1.6	2.1	1.0	1.0	0.8	1.0	0.6	0.9	1.1	1.7	1.4	3.0	1.4	1.7	0.0	0.0	0.4	0.0	0.0	1.0	0.8	1.6	0.8
20	2.0	1.9	1.3	1.0	1.1	0.8	0.5	1.0	0.9	1.0	1.8	2.0	1.5	1.7	1.0	0.0	1.4	0.8	0.0	0.0	1.1	0.0	2.0	1.0
21	2.3	1.7	1.5	0.9	1.0	1.0	0.8	1.0	1.2	0.0	1.8	1.0	0.4	0.6	0.3	0.0	1.7	0.9	0.0	0.0	0.8	0.0	1.0	1.2
22	3.1	2.2	0.8	1.0	1.0	0.8	0.7	1.3	0.5	0.0	2.9	1.4	1.5	1.2	0.7	0.4	1.5	0.4	0.0	0.2	0.3	0.0	0.0	1.8
23	2.7	1.6	1.0	1.4	1.3	1.3	1.0	1.4	0.5	0.9	2.8	.....	1.9	1.3	0.0	0.8	2.0	1.3	0.1	1.0	0.3	0.0	2.0	.....
24	2.2	2.0	1.3	1.0	1.8	1.3	0.4	1.0	0.9	1.0	2.6	.....	1.8	1.7	0.2	1.2	0.6	1.7	0.0	1.6	0.3	0.0	2.3	.....
25	2.4	1.6	1.4	1.2	2.0	0.9	0.6	2.0	0.6	1.2	2.7	1.7	1.2	1.0	0.4	1.4	0.4	1.5	0.5	1.8	0.6	0.4	3.3	1.6
26	2.2	1.2	1.4	0.9	2.0	0.3	1.7	2.0	0.5	1.1	.....	1.0	1.8	0.0	0.7	0.3	0.6	0.5	1.0	1.5	0.0	0.3	.....	1.2
27	2.2	1.6	1.6	1.4	2.1	0.9	1.3	2.0	1.0	1.3	3.9	1.8	1.8	1.8	1.7	1.3	1.7	0.8	1.1	0.1	0.0	1.7	3.6	1.2
28	2.0	2.0	1.7	1.5	1.8	1.0	1.2	2.0	1.0	1.8	3.0	1.7	2.2	2.7	1.6	1.6	1.7	0.0	0.7	0.9	0.0	2.4	2.7	0.6
29	1.2		1.9	2.2	2.2	1.0	1.7	2.4	.....	1.7	2.6	.....	1.6		1.9	1.4	2.0	0.6	1.6	2.1	.....	2.3	2.0	.....
30	2.4		2.2	1.7	1.5	1.0	1.6	1.9	1.1	2.3	2.3	1.7	1.4		1.8	1.8	1.4	1.2	1.4	1.4	1.0	3.6	2.0	1.6
31	1.4		2.5		2.0		1.0	1.9		2.7		1.0	1.0		2.0		1.2		1.6	1.6		2.1		0.4
Means	2.4	2.2	1.9	1.7	1.5	1.1	1.1	1.9	1.7	1.6	1.8	1.1	1.9	1.6	1.4	1.2	1.1	1.0	0.8	0.7	1.0	1.2	1.3	0.8

Day	Calcium flocculi—Whole disc											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	3.1	2.8	2.4	2.4	2.0	2.1	1.6	1.5	2.1	1.7	2.4	2.5
2	3.0	3.0	2.8	3.0	2.0	2.6	2.0	1.2	2.1	1.9	2.4	1.9
3	2.9	3.0	2.8	2.9	2.0	2.0	1.8	1.2	2.5	1.6	2.3	1.7
4	1.6	3.1	2.8	2.9	2.2	1.3	1.8	1.0	2.7	1.6	1.7	1.8
5	2.0	3.2	2.9	2.9	2.7	1.3	2.2	0.8	2.7	2.2	1.8	1.4
6	2.2	3.2	2.6	2.6	3.2	1.6	2.0	0.8	2.8	2.1	1.9	1.3
7	2.9	3.4	2.7	2.5	2.6	2.0	1.8	0.9	2.8	2.1	1.8	0.6
8	3.6	3.5	2.7	2.7	1.9	2.0	1.6	1.1	2.9	1.9	2.0	0.3
9	3.7	3.0	2.4	2.6	1.9	2.1	1.6	1.2	3.1	2.2	2.2	0.3
10	3.5	3.0	2.9	3.0	1.7	2.1	1.7	1.3	2.7	2.4	2.0	1.0
11	3.4	3.0	2.6	2.9	1.6	2.0	1.5	1.3	2.3	2.2	1.4	1.2
12	2.9	2.7	2.7	2.6	1.5	2.2	1.4	1.3	2.2	2.6	1.2	1.1
13	3.3	2.5	2.3	2.8	1.5	1.5	1.0	1.1	2.1	2.7	1.2	1.1
14	3.0	2.2	2.2	2.2	1.2	1.3	0.9	1.3	2.0	2.6	1.1	1.4
15	2.7	2.2	1.6	2.0	1.3	1.1	1.5	1.1	1.8	2.6	1.1	2.0
16	3.4	2.2	2.1	1.6	1.2	1.5	1.4	1.0	1.7	2.5	1.3	2.0
17	3.1	2.2	1.9	1.6	1.8	1.6	1.4	1.0	1.4	1.5	1.4	1.7
18	3.0	2.5	2.4	1.5	1.6	1.5	1.3	0.6	1.4	1.4	1.7	2.0
19	3.0	2.4	2.3	1.1	1.3	1.3	1.1	0.9	1.4	1.3	2.2	2.0
20	2.9	2.5	2.3	1.3	1.2	1.4	1.2	1.0	1.4	1.2	2.3	2.1
21	3.5	2.5	2.2	1.4	1.4	1.5	1.0	1.4	1.3	0.4	2.4	2.2
22	3.4	2.4	1.4	1.8	1.3	1.6	0.9	1.3	1.3	0.0	2.6	3.2
23	3.1	2.3	1.7	1.9	1.8	1.8	0.8	1.4	1.2	0.6	2.9	1.7
24	3.4	2.2	2.0	1.4	2.0	1.4	1.0	1.6	1.3	1.1	2.8	2.0
25	3.4	2.6	2.0	1.6	2.0	1.7	1.4	2.1	0.9	0.9	3.0	2.9
26	2.9	2.5	2.0	1.8	2.2	1.1	1.8	2.0	1.1	1.3	2.7	2.6
27	2.7	2.2	2.3	2.0	2.2	1.2	2.1	2.1	1.3	2.1	3.0	2.3
28	2.7	2.2	2.3	2.2	2.2	1.3	2.1	2.2	1.1	2.1	3.1	2.3
29	3.0		2.4	2.0	2.6	1.1	2.0	2.1	0.9	2.1	2.5	1.6
30	3.1		2.3	2.1	2.6	1.4	1.8	2.2	1.8	2.0	2.8	1.7
31	2.6		2.4		2.1		1.6	2.2		2.1		1.4
Means	3.0	2.5	2.3	2.2	1.9	1.6	1.5	1.4	1.9	1.8	2.1	1.7

Day	Calcium flocculi—Central disc											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	1.7	1.2	2.0	2.4	1.6	1.0	1.9	1.3	1.7	1.8	0.8	2.0
2	0.9	1.9	2.0	2.7	1.8	1.4	1.8	1.0	1.0	1.9	0.4	1.6
3	0.8	2.1	1.5	2.6	1.8	1.6	1.5	1.2	1.4	1.9	0.4	1.3
4	0.5	2.1	0.9	2.1	1.1	1.8	1.3	0.8	1.7	1.2	1.1	1.1
5	0.5	2.6	1.9	1.5	1.7	1.4	1.6	0.6	2.0	1.0	1.9	0.8
6	1.4	2.4	2.9	2.3	2.0	1.7	1.7	0.5	2.2	1.0	1.8	0.5
7	3.3	2.9	3.0	2.2	1.8	1.8	1.8	0.2	2.3	0.5	2.0	0.5
8	3.2	3.0	2.7	2.4	1.8	1.8	1.6	0.4	2.4	0.8	2.0	0.0
9	2.8	2.9	2.6	1.8	0.8	1.9	1.0	0.4	2.8	2.3	2.0	0.0
10	2.8	2.8	1.3	1.0	0.9	1.9	0.2	1.5	2.2	2.0	1.6	0.0
11	2.6	1.4	1.0	2.0	1.0	1.9	0.0	1.9	2.0	2.4	1.1	0.0
12	2.4	1.2	1.3	2.2	1.1	2.2	0.2	2.2	1.9	2.4	0.9	0.0
13	3.8	1.7	1.1	1.8	1.2	1.2	0.6	1.4	1.5	1.7	0.3	0.6
14	2.5	1.8	0.9	1.7	1.3	0.5	0.8	0.7	0.7	1.8	0.2	1.6
15	1.4	1.7	0.4	1.3	1.1	0.0	1.4	0.0	0.7	1.8	0.2	2.2
16	1.2	1.2	1.5	0.6	1.0	0.4	1.6	0.0	0.7	1.7	0.1	2.2
17	2.5	1.2	2.0	0.3	0.9	0.7	1.5	0.0	0.8	1.2	1.2	1.3
18	2.8	1.8	2.6	0.4	0.5	0.8	1.0	0.0	1.8	0.8	2.0	0.8
19	2.5	2.0	1.5	0.2	0.2	1.1	0.4	0.2	1.8	0.2	2.2	1.1
20	2.2	2.1	1.2	0.2	0.7	1.1	0.3	0.0	1.5	0.2	1.8	1.1
21	2.0	1.5	0.9	0.6	1.3	1.2	0.4	0.2	1.1	0.0	1.9	2.3
22	2.2	1.4	0.7	0.8	2.1	1.3	0.2	0.7	0.8	0.0	0.7	2.5
23	2.0	1.3	0.9	1.4	1.6	1.5	0.2	2.0	0.7	0.0	1.8	2.4
24	2.2	1.6	0.9	0.9	0.9	1.8	0.4	2.4	0.8	0.0	2.2	2.6
25	1.8	1.3	0.9	1.0	0.9	1.8	1.0	2.4	0.6	0.7	3.1	2.9
26	1.6	1.0	1.1	1.0	1.4	1.7	1.5	1.8	0.2	0.5	3.4	2.1
27	1.8	1.5	1.7	1.6	2.3	1.1	1.9	0.6	0.2	1.3	3.0	1.6
28	1.7	2.0	2.1	2.0	2.6	0.6	1.8	1.0	0.0	2.1	2.8	1.1
29	2.0		2.5	1.8	2.5	1.0	1.9	1.9	0.0	2.2	2.2	1.5
30	1.4		2.0	2.1	2.2	1.0	1.7	2.0	1.0	2.0	1.8	1.5
31	1.3		2.6		1.5		1.4	2.4		1.4		1.2
Means	2.0	1.8	1.6	1.5	1.4	1.3	1.1	1.0	1.3	1.2	1.6	1.3

TABLE 2—*Corrected daily means of solar indices, 1930*—Continued

Day	Dark H_α—Whole disc												Dark H_α Central disc											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	2.7	2.8	2.0	2.4	2.0	2.2	2.0	1.8	1.0	1.6	1.7	3.5	3.3	1.9	1.9	3.7	1.9	1.7	1.5	2.0	1.2	0.7	1.2	1.9
2	2.7	3.2	1.6	2.8	1.6	1.8	2.0	1.8	0.7	1.8	1.7	3.5	3.0	3.3	0.8	3.7	1.1	1.4	1.7	1.7	0.9	1.6	0.0	1.9
3	3.5	2.7	2.5	2.4	2.0	1.3	1.8	2.2	1.0	2.2	1.1	1.8	2.7	2.7	1.9	3.7	0.3	0.9	1.2	1.8	1.3	1.6	0.2	1.9
4	3.2	2.4	2.3	2.7	1.9	1.6	2.0	1.4	1.3	2.9	1.8	2.6	2.0	1.9	3.1	1.6	0.3	0.8	0.9	1.5	1.5	1.5	0.6	2.3
5	.....	2.8	2.9	3.8	1.9	2.1	2.0	1.0	1.1	3.4	3.5	2.9	.....	1.3	2.7	1.3	0.5	1.1	1.0	0.0	0.3	0.8	1.9	1.7
6	2.8	1.5	3.0	3.7	1.9	2.1	1.8	1.3	1.6	2.2	2.3	4.6	0.5	1.3	4.3	1.1	1.2	1.6	1.5	0.0	1.5	1.4	2.1	2.0
7	1.5	2.3	3.2	4.2	1.9	1.7	1.6	1.0	2.0	2.6	2.1	3.4	1.8	1.8	4.0	1.3	1.2	1.0	1.1	0.0	2.0	0.8	2.0	1.6
8	2.2	1.9	3.3	3.0	2.0	1.5	1.9	1.2	2.0	3.3	3.5	2.2	1.8	1.7	3.3	2.5	1.2	1.1	1.0	1.2	2.6	0.7	1.9	0.4
9	2.2	2.2	3.7	3.2	2.0	1.8	1.7	1.0	2.2	.....	3.5	2.6	1.5	1.5	3.5	3.2	1.2	0.4	1.0	1.8	0.9	.....	1.5	0.6
10	2.1	2.0	3.1	3.0	2.5	2.1	1.8	1.0	2.0	1.3	3.1	2.0	1.2	1.6	1.7	2.9	1.7	0.0	0.6	0.9	1.0	1.2	0.8	0.6
11	1.5	3.1	3.6	3.1	2.7	1.3	1.9	1.0	2.0	.....	2.4	1.7	1.4	1.9	0.8	3.0	1.3	0.0	1.0	0.9	0.4	.....	0.4	0.8
12	0.8	2.6	3.0	3.0	2.6	1.0	1.7	1.0	2.0	1.8	2.6	2.1	1.6	0.6	1.4	2.0	1.4	0.3	1.3	1.0	1.3	0.5	0.6	0.8
13	2.0	2.8	3.1	3.2	2.6	1.4	1.3	1.3	2.0	1.5	2.6	2.2	1.4	1.2	1.7	1.1	0.5	0.9	0.9	1.8	0.9	0.9	1.7	1.1
14	2.4	3.0	2.9	3.1	2.2	1.0	1.3	2.0	2.0	1.5	2.1	1.8	1.6	0.3	2.7	1.4	0.7	0.5	1.2	1.6	1.8	0.0	1.6	0.7
15	.....	2.0	2.4	2.1	2.0	1.0	2.0	3.1	1.7	0.9	3.4	2.1	.....	1.6	2.4	1.3	0.0	0.9	1.8	1.5	1.1	0.3	0.8	1.3
16	1.5	2.2	3.3	2.2	2.5	1.0	2.5	3.0	1.5	2.5	3.3	2.0	1.0	2.6	2.3	1.4	0.0	1.4	1.4	1.8	1.3	0.7	1.5	1.2
17	1.0	2.9	4.0	1.3	2.8	1.7	2.5	2.9	1.0	1.8	2.1	1.4	0.0	2.8	4.0	0.0	0.0	1.4	1.4	1.5	0.6	0.4	1.8	0.0
18	1.4	2.7	2.9	1.6	2.1	2.5	2.4	2.7	1.7	2.7	2.3	1.7	1.7	2.9	3.1	0.5	1.3	1.7	0.4	1.0	1.2	1.5	1.4	0.5
19	2.0	2.2	3.6	1.6	1.8	1.5	2.6	2.5	1.5	2.3	3.5	1.7	1.9	0.9	2.4	0.5	1.3	0.5	1.6	1.2	0.4	1.5	1.0	0.0
20	1.5	3.0	3.3	1.7	2.0	1.4	3.6	2.3	2.2	2.6	1.7	1.8	1.7	1.2	0.5	0.3	1.5	0.8	2.7	1.3	1.8	2.6	0.4	0.5
21	1.8	2.7	3.4	2.0	2.6	2.2	3.3	1.7	2.0	2.2	1.7	1.6	1.2	1.6	1.9	0.2	1.6	1.4	3.9	1.0	2.2	0.0	0.0	0.0
22	2.0	1.9	3.3	1.6	2.2	2.2	3.1	1.6	1.0	0.0	1.6	1.7	1.4	1.6	2.6	1.0	1.4	1.0	3.2	1.0	0.9	0.0	0.0	0.8
23	2.4	1.6	3.1	2.6	2.5	2.4	2.8	1.3	1.0	3.5	1.1	.....	1.4	0.3	2.5	1.4	2.0	2.0	1.5	0.4	0.9	0.0	1.0	.....
24	2.9	1.9	2.5	1.9	3.1	2.8	2.2	1.0	1.0	0.0	3.5	.....	1.2	0.9	2.2	1.7	2.1	2.3	1.8	0.5	0.6	0.0	1.9	.....
25	2.4	2.0	2.3	2.6	3.7	2.5	2.3	0.9	0.6	0.0	2.4	3.5	1.6	1.4	2.1	1.5	1.8	1.7	0.9	0.5	0.0	0.0	2.9	1.9
26	2.9	1.6	1.5	3.0	3.7	1.8	2.0	0.6	1.0	0.5	.....	1.6	1.6	0.8	1.2	1.3	2.7	1.3	1.5	0.9	0.0	0.0	.....	0.7
27	3.7	1.4	2.3	2.7	3.6	2.5	1.6	0.6	1.0	1.5	1.6	2.6	4.3	1.6	1.9	1.3	2.9	0.9	1.7	0.9	1.4	0.2	1.5	0.8
28	3.6	2.4	2.6	2.9	3.3	1.7	1.1	0.3	0.0	1.7	2.0	2.0	4.2	1.6	1.6	1.0	2.0	0.3	0.3	0.0	1.2	1.3	0.8	0.9
29	3.6		2.5	2.3	3.8	1.8	1.3	0.4	.....	3.5	2.6	.....	3.8		1.4	1.5	0.8	1.0	0.9	0.0	.....	1.9	0.4	.....
30	3.5		2.7	3.0	3.8	1.8	1.5	0.8	0.0	3.4	1.4	3.5	3.9		2.0	3.0	1.0	1.3	0.0	0.0	0.0	1.7	0.5	1.0
31	3.2		2.5		3.1		1.5	1.0		2.3		1.8	3.4		3.0		1.8		0.3	1.0		1.6		1.3
	[illegible]	[illegible]	[illegible]	[illegible]	2.5	1.8	2.0	1.5	1.4	2.0	2.3	2.4	2.0	1.6	2.2	1.7	1.2	1.0	1.3	1.0	1.1	0.9	1.1	1.0

PRELIMINARY REPORT OF THE MAGNETIC OBSERVATIONS MADE DURING THE AEROARCTIC EXPEDITION OF THE *GRAF ZEPPELIN*, 1931

By Gustaf S. Ljungdahl

The magnetic work during the arctic expedition of the airship *Graf Zeppelin* in July 1931 was undertaken for the purpose of studying the possibilities of making magnetic measurements under the conditions involved and of obtaining as valuable observations as possible.

A preliminary report of the results is here presented. In the reduction of the observations, I hope later to have the privilege of utilizing the registrations of Sloutzk and Matotchkin Shar. It is to be noted that *the present values have not been reduced.* The geographical *positions* have been fixed by interpolation from the time-records. The positions as given in Tables 1 and 2 are preliminary. They will be recalculated and in a later, more complete, report probably somewhat corrected.

Horizontal intensity—The determinations of the horizontal intensity (H) were made with the double compass[1], subsidized by the Carnegie Institution of Washington. The instrument occupied the same position in the airship as on the previous flights of Dr. Grotewahl[2] to Seville, and of Drs. Haussmann and Nippoldt to Mannheim[3]. After these flights the instrument was somewhat altered and the constants redetermined at the Magnetic Observatory at Potsdam by Dr. Fanselau.

The computations of H have been made using the simple formula $H = C_e \cos \psi/2$ where ψ is an angle to be observed and C_e is a constant depending on the distance e between two compass-cards. Two distances were used and the corresponding constants were $C_1 = 0.24614$ and $C_{max} = 0.15272$. C_e is in reality not quite constant but requires some small correction[4].

The angle ψ is the average of 80 readings from which at first eight separate means were formed. The mean error of ψ, in Table 1, is computed from these eight means. When the mean error occurs in parentheses, it is computed from only four means, resulting from readings with the compass-cards in only the one position.

The mean error signifies merely the relative accuracy of the observation but indicates nothing as regards the absolute accuracy, the influence of deviation, etc.[5] In order to give an idea of the accuracy, I have plotted in Figure 2 some land stations, according to the Catalogue of Weinberg[6]. These values have been reduced to epoch 1931 with the aid of data kindly communicated by Prof. Rose of Leningrad. Not all the sta-

[1]F. Bidlingmaier, Der Doppelkompass, seine Theorie und Praxis. Deutsche Südpolar-Expedition 5, Erdmagnetismus I.

[2]M. Grotewahl, Bericht über die Versuchsfahrt des Bidlingmaierschen Doppelkompasses mit dem Luftschiff Graf Zeppelin. Terr. Mag., **35**, 226-229 (1930).

[3]G. Fanselau, Messungen mit dem Doppelkompass im Luftschiff. Arktis, **4**, 14-18 (1931).

[4]G. Fanselau, Ueber Messungen mit dem Doppelkompass. Berlin, Ber. Met. Inst., 1930, 186-193 (1931).

[5]The influence of deviation due to iron or electric currents, seems to be very small. See Grotewahl, Terr. Mag., **35**, 228 (1930).

[6]B. P. Weinberg, Catalogue of magnetic determinations in U. S. S. R. and in adjacent countries from 1556 to 1926. Leningrad, Central Geophysical Observatory (1929).

tions in the neighborhood of the route traversed by the airship have been taken but only those of recent years. In Figure 1 the values obtained during the flight are given. The values for the eastern parts of the route, over the Taimyr Peninsula and also over Novaya Zemlya, seem to be in good agreement with the values at the land stations.

From this comparison the absolute accuracy seems to be within $\pm 100\gamma$ or perhaps $\pm 150\gamma$. The difference between the double-compass determinations and those of the land stations is, naturally, due to some extent

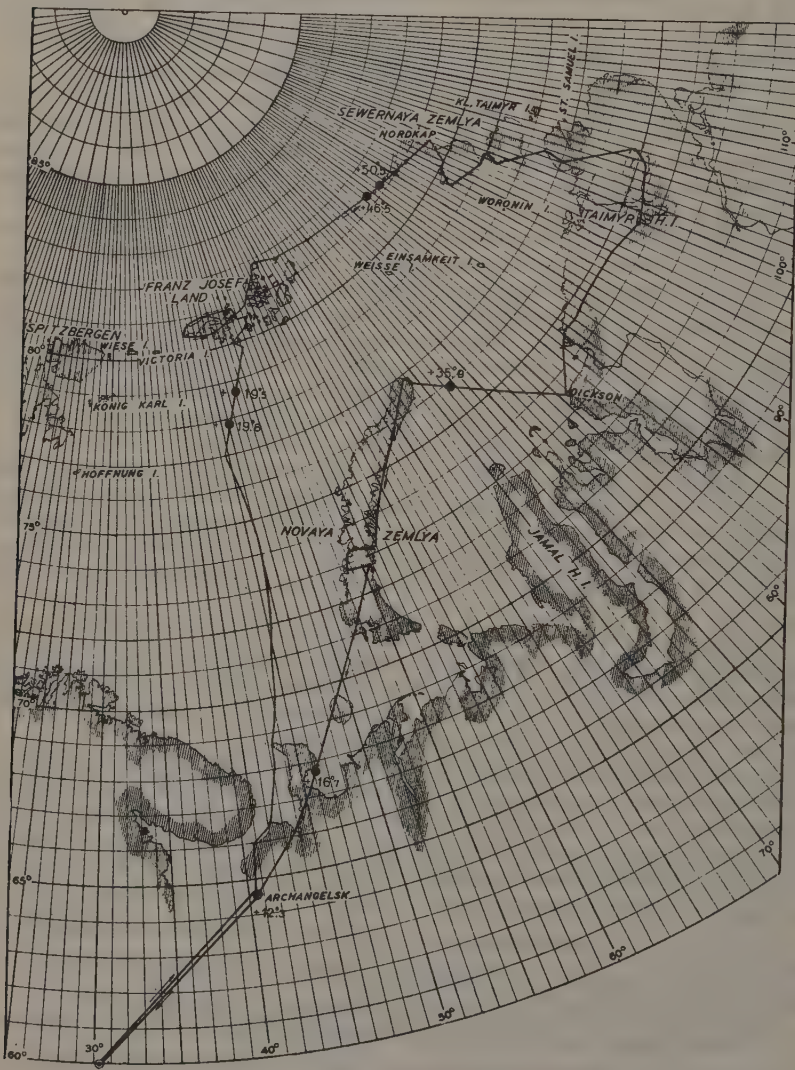

FIG. 1—Preliminary results of horizontal intensity obtained on the *Graf Zeppelin*, during her arctic cruise, July 26-30, 1931

to the reductions to the common epoch. The agreement in the neighborhood of Archangelsk is less satisfactory owing probably to anomalies.

On the flight from Friedrichshafen to Leningrad the differences, according to a preliminary computation from the observations at the land stations, give a correction of $-56\gamma \pm 48\gamma$, and on the flight from Leningrad to Berlin of $-53\gamma \pm 27\gamma$. The results are given in Table 1 and Figure 1.

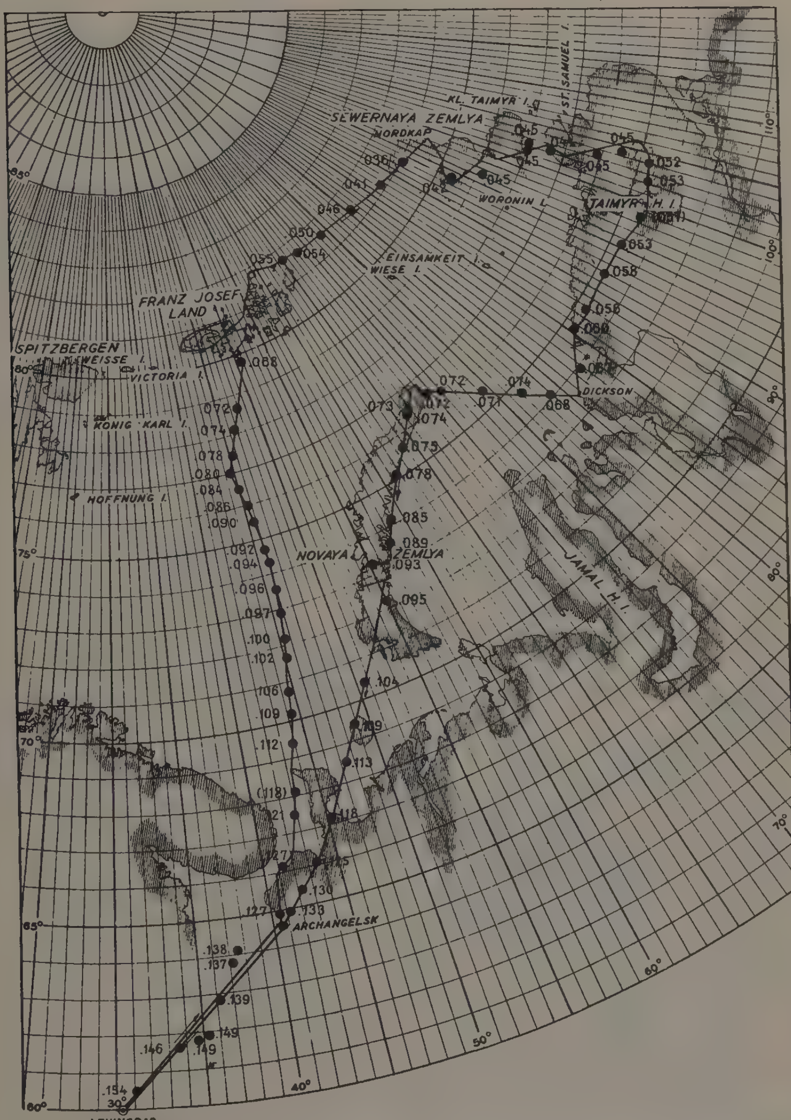

FIG. 2—Values of horizontal intensity for 1931, according to Weinberg, at land stations along the arctic route of the *Graf Zeppelin*, July 26-30, 1931

Declination—During the flight an attempt was made to determine the declination (D) with a Thomson compass-rose with fibre suspension, according to a model of Dr. Haussmann, by projection of the Sun's shadow on the card. To diminish the influence of air-currents, the rose was inclosed in a wooden box with a glass cover. A hole in the cover permitted the passage of the fibre. The instrument was placed in one of the two stern windows of the saloon of the airship where the deviation should

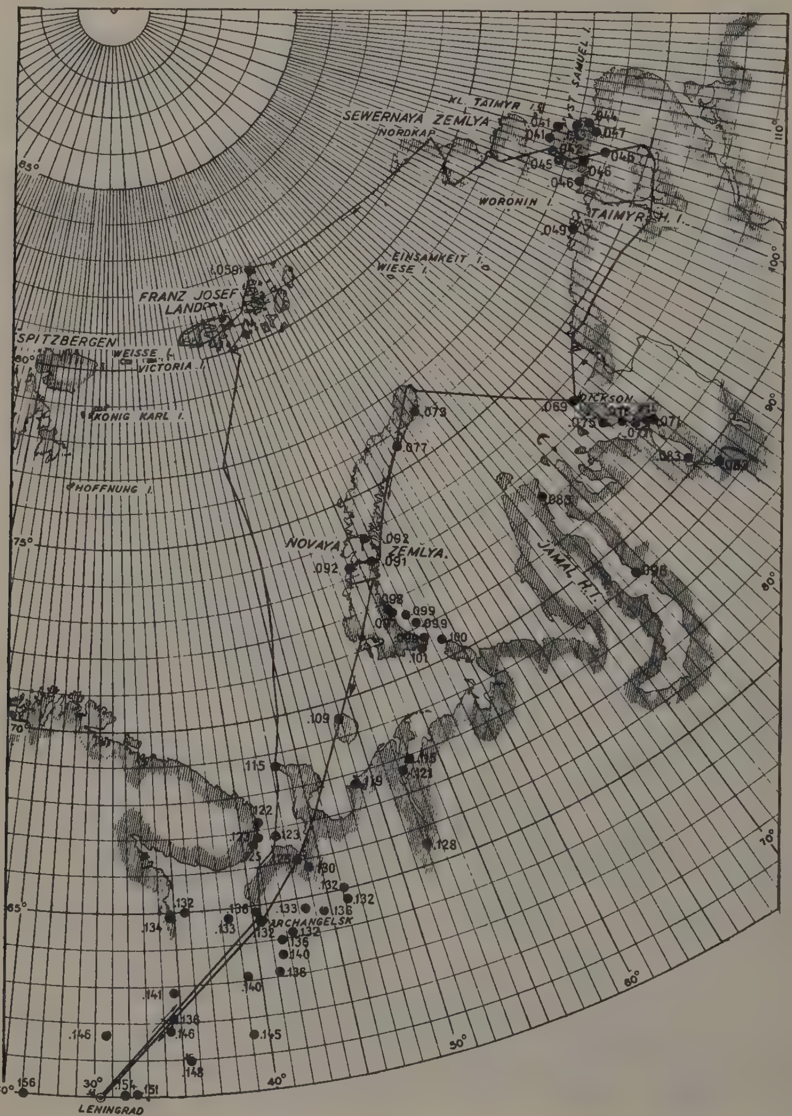

FIG. 3—Preliminary results of declination obtained on the *Graf Zeppelin*, during her arctic cruise, July 26-30, 1931

TABLE 1—*Preliminary results of horizontal-intensity determinations*
(*Observers:* L. Ellsworth, E. H. Smith, G. S. Ljungdahl)

Lat. north	Long. east	Date	G. M. T.	e	ψ		Horizontal intensity		Altitude
°	°	*1931*	*h m m*		°	°	*c. g. s.*		*m*
60.3	31.1	July 26	8 36–48	1	102.7	±0.3	0.1538	±0.0005	200(?)
61.8	34.7	26	11 06–17		105.8	0.7	.1486	12	250
61.9	35.3	26	11 21–36		105.8	0.4	.1486	07	250
63.8	37.1	26	14 12–22	1	112.6	0.2	.1367	04	250
64.1	37.5	26	14 26–36	Max.	51.9	0.1	.1379	01	250
64.9	40.5	26	17 11–20		67.8	0.5	.1272	04	200
66.2	41.4	26	18 20–32		68.1	0.3	.1269	03	200
67.5	42.9	26	20 40–60		75.6	1.6	.1209	13	150
68.1	43.2	26	21 50–78		78.7	2.4	.1181	20	150
69.4	43.8	27	0 01–13		85.5	1.2	.1121	11	200
70.2	44.4	27	1 22–30		88.8	0.7	.1091	07	200
70.7	44.6	27	2 07–20		92.2	0.3	.1059	03	200
71.6	45.2	27	3 33–45		96.3	0.3	.1019	02	150
72.2	45.5	27	4 31–40		97.8	0.3	.1004	02	150
72.9	45.8	27	5 30–50		100.7	1.0	.0974	10	150
73.6	46.0	27	6 45–65		101.8	0.7	.0962	08	130
74.3	46.0	27	8 10–20		104.4	0.6	.0935	06	130
74.7	46.0	27	9 09–20		106.1	0.3	.0918	03	150
75.5	45.9	27	10 03–13		108.2	0.4	.0896	04	150
76.0	45.5	27	11 06–16		111.1	0.3	.0864	03	150
76.5	45.0	27	12 02–21		113.3	0.3	.0840	04	150
77.0	44.5	27	13 03–13		117.0	0.9	.0798	10	150
77.4	45.4	27	14 00–10		118.6	0.4	.0780	05	150
78.1	46.9	27	15 00–09		121.6	0.4	.0745	04	200
78.5	48.0	27	15 50–70		123.6	0.5	.0722	05	200
79.8	50.8	27	16 55–66		127.1	0.3	.0680	03	200
81.7	65.0	28	0 25–29		138.0	(0.1)	.0547	(02)	1000
81.6	68.1	28	1 05–14		138.6	0.2	.0540	03	500
81.6	73.5	28	2 02–12		141.9	0.2	.0498	03	500
81.4	80.5	28	3 03–12		144.9	0.3	.0460	04	500
81.2	87.5	28	4 00–20		148.6	0.6	.0411	08	500
80.9	92.8	28	5 00–13		152.0	0.9	.0364	12	500
79.6	94.0	28	8 00–17		148.2	0.8	.0419	10	1150
78.9	96.2	28	9 00–18		145.6	0.6	.0451	08	1150
78.0	101.2	28	10 05–19		145.8	0.8	.0448	10	1150
78.0	102.3	28	10 48–52		145.7	(0.1)	.0449	(02)	1150
77.4	102.2	28	11 14–18		146.7	(0.2)	.0437	(03)	1150
76.1	103.3	28	12 03–14		145.4	0.6	.0453	07	1150
75.5	104.4	28	13 00–08		145.4	0.2	.0453	03	1150
74.7	104.1	28	14 03–15		139.8	0.3	.0525	03	1100
74.6	102.2	28	14 55–64		139.1	0.3	.0534	04	1100
74.5	98.7	28	16 00–20		136.3	1.2	.0568	15	1050
74.7	95.4	28	17 00–14		139.1	0.6	.0534	08	1050
74.7	91.9	28	18 00–15		135.8	0.7	.0575	08	800
74.7	87.8	28	19 00–15		137.1	0.8	.0558	10	800
74.7	85.5	28	19 58–63		133.4	(0.6)	.0604	(07)	800
73.9	82.7	28	21 06–21		128.1	0.9	.0668	12	800
74.1	78.9	28	23 07–22		127.4	0.4	.0677	05	350
74.7	77.0	29	0 00–10		121.9	0.3	.0742	04	250
75.4	74.3	29	0 59–67		124.6	0.3	.0711	03	250
76.2	71.0	29	2 00–09		123.7	0.2	.0722	03	200
76.5	69.5	29	2 39–41		123.3	(0.5)	.0725	(06)	200
76.4	66.8	29	3 39–41		123.1	(0.1)	.0728	(01)	1300
76.4	66.8	29	3 44–48		122.4	(0.2)	.0736	(03)	1300
75.8	63.8	29	4 43–59		120.9	0.5	.0753	06	1300
75.1	61.6	29	5 35–55		118.5	0.3	.0781	03	1300
74.2	58.8	29	7 02–12		112.1	0.3	.0853	03	1300
73.6	57.6	29	7 58–73		108.6	0.2	.0891	02	1300

Lat. north	Long. east	Date	G. M. T.	e	ψ		Horizontal intensity		Altitude
°	°	*1931*	*h m m*		°	°	*c. g. s.*		*m*
73.3	55.2	29	9 50–60		105.1	0.4	.0929	04	800(?)
72.3	55.0	29	10 44–52		103.3	0.2	.0948	02	1200
70.4	50.8	29	12 46–52		94.7	0.2	.1035	02	700
69.5	48.9	29	13 46–52		89.1	0.3	.1088	02	1320
68.5	47.5	29	14 41–49		84.2	0.4	.1133	04	1320
67.1	45.2	29	16 00–15		78.2	1.0	.1185	09	1150
66.1	43.7	29	17 00–15		70.8	0.6	.1248	05	1150
65.4	42.2	29	18 00–20		64.1	0.2	.1298	01	1150
64.9	41.2	29	18 45–61		58.8	1.0	.1335	07	1150
62.8	36.1	29	21 21–42	Max.	50.9	0.3	.1386	02	1000
61.6	33.8	29	23 15–30	1	107.1	±0.6	0.1463	±0.0011	1100

have been very small. Only a few determinations were made owing to the difficulties of taking the Sun's bearing from the compass-position.

The undamped compass-rose often was subject to great and, unfortunately, irregular oscillations and vibrations. Accordingly, the results are probably not very exact. The first observation, in the vicinity of Stettin, requires, as compared with the results from land stations, a correction of $-0°.9$, the second, at Archangelsk, of $-1°.6$. The latter is comparatively bad due to yawing of the ship (see Table 2). The accuracy of the determinations is very difficult to appreciate but it seems quite impossible that the errors should be greater than $\pm 2°$ or $3°$.

The two stations between Franz Josef Land and Sewernaya Zemlya (Nicolaus II Land) are in good agreement with one another, but differ from the known values at land stations on Sewernaya Zemlya[6]. The observation to the east of Novaya Zemlya also differs from the land-station values. Nevertheless, I cannot find any reason why these three observations mentioned should be impaired by any special errors. The results are given in Table 2 and Figure 3.

Vertical intensity—For measurements of the vertical intensity (Z) the use of a galvanic instrument to be made at the Potsdam Magnetic Observatory was first considered. This instrument, however, could not be ready in time to be tested and used during the flight. Instead an available Schmidt field-balance was by way of trial, mounted in gimbals and taken on board. The sensitivity was diminished from 30γ to about 200γ per scale-division. This instrument, which is excellent for field work, could also easily be used with oscillating gimbals, but during the flight no measurements could be obtained owing to slipping of the magnet-system caused by vibrations of the airship.

It affords me great pleasure to express my sincere thanks to my collaborators during the flight, Lieutenant-Commander E. H. Smith and Mr. Lincoln Ellsworth, to Dr. G. Fanselau for the determinations of the constants, and to Dr. K. Haussmann and Dr. A. Nippoldt, for most valuable aid and service.

TABLE 2—*Preliminary results of determinations of declination*
(*Observer:* G. S. Ljungdahl)

Lat. north	Long. east	Date	G. M. T.	Readings	Declination	Side*	Altitude
°	°	*1931*	*h m*	°	°		*m*
		July 25	5 37	266.5	2.3W		
			40	269.5	4.7		
			42	266.5	1.3		
			43	268.0	2.6		
			43	268.8	3.4		
54.0	15.4				2.9W±0.6	*S*	250
		July 26	16 17	94	16.3 E		
			20	98	13.0		
			25	99	13.0		
			29	106	6.9		
64.6	40.6				12.3 E±2.0	*P*	200
		July 27	14 33	68.5	18.7 E		
			44	70.5	19.5		
			51	71	20.7		
77.8	46.1				19.6 E±0.5	*P*	150
		July 27	15 15	76	23.0 E		
			16	81	18.4		
			18	80	19.7		
			19	82	18.0		
			20	81	19.2		
			21	81	19.4		
			23	82	18.9		
78.7	48.0				19.5 E±0.6	*P*	200
		July 28	3 28	264	47.7 E		
			29	266	45.9		
			32	268.5	44.2		
			33	266	47.0		
			39	267	47.5		
81.2	83.9				46.5 E±0.6	*S*	500
		July 28	4 06	274.5	50.3 E		
			08	274	51.3		
			09	276	49.9		
81.2	87.0				50.5 E±0.4	*S*	500
		July 29	1 24	230.5	36.5 E		
			25	231.5	35.7		
			25.5	231.5	35.9		
			26	231.5	36.0		
			29	233	35.2		
75.8	72.5				35.9 E±0.2	*S*	250
		July 29	15 30	86	17.8 E		
			32	88	16.2		
			33	88	16.4		
			36	88	17.1		
			40	90	16.0		
67.7	46.1				16.7 E±0.3	*S*	1150

* *S* indicates that the determination was made on the starboard side, *P* on the port side.

KUNGL. SJÖKARTEVERKET, *Stockholm, Sweden*

LETTERS TO EDITOR

(See also page 374)

PROVISIONAL SUNSPOT-NUMBERS FOR AUGUST, SEPTEMBER, AND OCTOBER, 1931

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	Aug.	Sep.	Oct.	Day	Aug.	Sep.	Oct.
1	23[aa]	33	10	17	*M*11[c]	28	0
2	*ME*35[ce]	27[a]	21	18	14	26	0
3	34	27	14	19	14	11	8[d]
4	28	19	18[a]	20	10	..	8
5	28	15	15	21	10	10[a]	10
6	19	15	15	22	0	*M*22[c]	9
7	8	14	7	23	..	22	24
8	0	18	8	24	0	16	18
9	..	13	7	25	0	7	..
10	0	*E*24[c]	0	26	*M* 8[c]	7	..
11	8	29	7	27	*M*26[cd]	15	11
12	0	*M*23[c]	0	28	36	17[d]	10
13	8	27	*M* 8[c]	29	25	10	9
14	0	26	9	30	24	11	..
15	0	19[d]	8	31	30		*W*18[c]
16	0	27	0				
				Means	13.8	19.2	9.7
				No days	29	29	28

Mean for quarter January to March, 1931: 28.4 (75 *days*)
April to June, 1931: 23.4 (88 *days*)
July to September, 1931: 16.6 (88 *days*)

[a]Passage of an average-sized group through the central meridian.

[b]Passage of a larger group through the central meridian.

[c]New formation of a large or average-sized center of activity; *E*, on the eastern part of the Sun's disc; *W*, on the western part; *M*, in the central zone.

[d]Entrance of a large or average-sized of activity on the east limb.

Zürich, Switzerland W. BRUNNER

PROVISIONAL SOLAR AND MAGNETIC CHARACTER-FIGURES, MOUNT WILSON OBSERVATORY, JULY, AUGUST, AND SEPTEMBER 1931

During the third quarter of 1931 only one storm was recorded during which the range in H exceeded 100γ. The hydrogen spectroheliograms of September 15 show a marked increase in the activity associated with the spot-group which was about 33° west of the central meridian at the commencement of this storm.

On July 23 a moderate storm began suddenly at $3^h\ 21^m$ G. M. T.

On September 15 a storm began at about 2^h G. M. T. and continued to September 17 at about 12^h, the range in H being 134γ.

Day	July 1931								August 1931								September 1931							
	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.
	A	B	A	B	A	B			A	B	A	B	A	B			A	B	A	B	A	B		
1	1	1	2	1	2	1	2	0	1	2	1	2	2	2	4[a]	0	2	2	2	2	1	1	3[a]	0.5
2	2	2	2	1	1	1	3	0.5	1	2	2	2	2	1	4	0	2	2	2	1	1	0	3[b]	0
3	2	3	2	2	1	2	3	0.5	1	1	2	2	1	0	4	0.5	...	...	...	...	...	...	...	0.5
4	2	3	2	3	2	2	2[c]	0.5	2	1	1	1	1	0	4	0	1	2	2	2	1	1	3	...
5	2	4	2	4	2	3	3	0	1	1	1	1	0	0	4	0	1	1	1	1	2	2	2	0.5
6	2	4	2	4	2	2	4	0	2	2	1	2	0	0	2	0	1	1	1	2	2	1	3	1.0
7	2	2	2	2	2	1	5	0	1	2	1	2	0	0	2	0.5	1	1	1	1	2	0	3	1.0
8	1	1	2	1	2	1	4	0	1	2	1	2	1	1	0	1.0	1	1	1	1	1	0	1	0.5
9	2	1	2	1	1	1	4	0	1	2	1	2	1	0	1	1.5	1	1	1	0	1	0	2	0.5
10	1	1	1	1	1	1	4[c]	0	1	1	1	1	1	1	2	0.5	1	0	1	0	2	0	2	0.5
11	1	1	1	1	1	0	4	0	...	...	...	...	...	...	1	0.5	1	0	1	0	1	0	3	0.5
12	1	1	1	1	1	0	4	0	...	...	...	...	...	...	...	...	1	1	1	0	1	0	4[c]	0
13	1	1	1	1	1	1	4	0	1	0	0	0	1	1	0	0	1	1	1	1	1	0	3	0.5
14	1	1	1	1	0	0	4	0.5	0	0	0	0	1	1	0	0	1	1	1	1	1	0	2	0
15	1	1	1	1	0	0	2	0.5	0	0	0	0	1	0	0	0	1	0	1	0	0	0	3	1.0
16	1	1	1	1	0	0	1	0.5	0	0	0	0	1	0	1	1.0	1	0	1	0	1	1	3	1.5
17	1	1	...	...	...	...	2	0	...	...	1	1	1	1	1	0	1	1	1	1	1	0	3	1.0
18	1	1	1	1	1	0	1	0.5	1	0	1	0	1	2	1	0	1	1	1	1	1	0	3	0
19	1	0	0	0	1	1	0	0	1	0	1	0	1	1	1	0.5	1	1	1	1	2	0	1	...
20	0	1	0	0	1	0	1	0	1	0	1	0	1	1	1	1.0	1	1	1	1	1	0	2	0.5
21	0	0	0	0	1	0	1	0	0	0	0	0	1	1	1	1.0	1	1	1	1	2	2	2[c]	1.0
22	...	...	...	...	...	...	1	0	0	0	0	0	1	0	0	0	1	1	1	1	2	1	2	0.5
23	0	0	1	1	2	3	1	1.0	0	0	0	0	1	0	0	0.5	1	2	1	2	2	3	2	0.5
24	1	1	1	1	2	2	1	1.0	0	0	0	0	1	1	0	0.5	1	1	1	1	2	2	2	0.5
25	1	1	1	1	2	2	0	1.0	1	1	0	0	1	2	0	1.0	...	...	...	...	...	...	...	0
26	1	1	1	1	2	0	1	1.0	1	1	1	1	2	3	3	0.5	1	1	1	0.5	2	2	0	0.5
27	...	...	...	...	...	...	...	0	1	1	1	1	2	3	4	1.0	1	0.5	1	0.5	1	0	0	0.5
28	1	1	1	0	2	2	1	1.0	...	...	...	...	...	...	4	0.5	1	0.5	0	0	1	0	1	...
29	1	1	1	0	1	2	2	0.5	...	...	...	...	...	...	4	0	...	...	...	...	...	...	1	0.5
30	1	2	1	1	2	3	2	0.5	...	...	...	...	...	...	3	...	1	0	1	0	1	0	1	...
31	1	2	1	2	2	2	2[c]	0	2	2	...	...	...	...	4	0.5								
Mean	1.1	1.4	1.2	1.2	1.4	1.2	2.3	0.3	0.8	0.8	0.7	0.8	1.0	0.9	1.9	0.4	1.1	0.9	1.1	0.8	1.3	0.6	2.1	0.5

[a], [b], [c] Passage of an average-sized group through the central meridian within 5°, 10°, 15° of the center of the disc, respectively.

Mount Wilson Observatory, Pasadena, California

SETH B. NICHOLSON
ELIZABETH E. STERNBERG

AMERICAN *URSI* BROADCASTS OF COSMIC DATA[1]

Beginning the middle of August 1931, Science Service, cooperating with the American Section of the International Scientific Radio Union (URSI), is adding to the cosmic data, collected and broadcast, information concerning aurora. These data are supplied daily by the Alaska Agricultural College and School of Mines at College, Alaska.

The aurora data as given out by Science Service have been decoded and added to the table of cosmic data which is published regularly in the JOURNAL. Under the general heading of aurora in the table, the first column gives the character of the day: 0 indicates no aurora; 1, faint; 3, moderate; 5, strong; 7, brilliant; and 9, no observation or no observations possible on account of cloudiness. The second column

[1]For previous announcements see Terr. Mag., **35**, 184-185 and 252-253 (1930); **36**, 54, 141, and 258-259 (1931)

Summary American URSI daily broadcasts

Date	August																		September							
	Magnetism				Sun-spot		Solar constant		Aurora										Magnetism				Sun-spot		Solar Constant	
	Char.	Type	G. M. T. begin. distur.		Groups	No.	Value	Char.	Char.	Duration	Cloudiness	Form		Area covered	Av. altitude	Position	G.M.T. greatest distur.		Char.	Type	G. M. T. begin. distur.		Groups	No.	Value	Char.
												without rays	with rays													
			h	m			cal			hrs					°		h				h	m			cal	
1	0	..	..	....	2	11	1.947	f	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	4	13	1.943	f
2	0	..	..	....	3	16	1.948	s	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	3	11	1.948	u
3	1	b	6	10	4	16	1.945	f	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	...	...	1.946	f
4	0	..	..	....	4	12	1.948	f	...	...	...	.....	.....	...	...	.....	...		1	o	1	....	3	7	1.942	s
5	0	..	..	....	2	5	1.946	s	...	...	...	.....	.....	...	...	.....	...		1	i	..	....	2	2	1.948	f
6	0	..	..	....	2	6	1.949	s	...	...	...	.....	.....	...	...	.....	...		1	i	..	....	3	3	......	..
7	0	..	23	30	1	1	1.943	f	...	...	...	.....	.....	...	...	.....	...		1	i	..	....	2	4	1.939	f
8	1	o	..	....	0	0	1.953	f	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	1	2	1.951	f
9	2	i	..	....	1	2	......	..	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	...	...	1.954	f
10	1	p	..	....	1	1	1.952	f	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	2	8	1.947	f
11	1	i	..	....	...	...	1.959	f	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	2	10	......	..
12	0	..	..	....	...	...	1.948	f	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	...	...	......	..
13	0	..	..	....	...	...	1.951	f	3	1	10	HB	R	0.2	60	N-NE-E	9		0	..	..	....	3	15	1.946	f
14	0	..	..	....	0	0	1.948	f	...	...	...	.....	.....	...	...	.....	...		0	..	..	....	...	...	1.957	f
15	0	..	..	....	0	0	1.948	s	0	...	8	.....	.....	...	...	.....	...		1	b	9	20	3	13	1.950	f
16	1	i	..	....	1	1	1.951	s	1	2	7	G	.....	0.6	40	NW-N-NE	9		1	o	1	....	...	...	1.945	f
17	0	..	..	....	1	6	1.946	s	...	...	...	.....	.....	...	...	.....	...		2	o	..	...*	3	9	1.943	s
18	0	..	..	....	2	10	1.943	s	3	1	5	HA	RB	0.4	60	NW-N-E	10		0	..	..	....	1	3	......	..
19	1	o	0	....	1	11	......	..	3	4	3	HA	RV	0.6	70	NW-NE-SE	8		0	..	..	....	1	1	......	..
20	1	p	..	....	1	6	1.923	u	3	5	2	HB	D	0.6	65	NW-NE-SE	9		0	..	..	....	2	3	......	..
21	1	i	..	....	1	5	1.941	f	0	...	5	.....	.....	...	...	.....	...		1	i	..	....	2	4	......	..
22	0	..	..	....	...	...	1.926	u	3	2	4	HB	D	0.4	50	N-NE-E	9		0	..	..	....	2	9	1.960	u
23	0	b	8	50	0	0	......	..	0	...	7	.....	.....	...	...	.....	...		0	..	..	....	2	6	1.933	u
24	1	p	20	....	0	0	1.934	u	3	4	0	HV	D	0.6	75	NW-N-E	9		0	..	..	....	2	6	1.937	s
25	1	i	..	....	...	...	1.941	f	3	4	3	HA	D	0.6	45	NW-N-E	8		0	..	..	....	...	...	1.939	s
26	1	p	..	....	4	6	1.942	s	1	3	0	HA	RB	0.4	60	N-NE-E	9		0	..	..	....	...	...	1.948	s
27	0	..	..	....	4	11	1.948	s	3	4	1	HB	RB	0.4	85	NW-NE-E	8		0	..	..	....	1	1	1.949	s
28	1	i	..	....	...	...	1.942	s	9	...	10	.....	.....	...	...	.....	...		0	..	..	....	1	2	1.953	f
29	0	..	..	....	4	8	1.943	s	0	...	5	.....	.....	...	...	.....	...		0	..	..	....	1	2	1.945	f
30	0	..	..	....	3	5	......	..	0	...	7	.....	.....	...	...	.....	...		0	..	..	....	1	2	1.946	s
31	0	..	..	....	4	11	1.946	f	0	...	2	.....	.....	...	...	.....	...		...	..	..	....	...	...	......	..
Mean	0.4	..	..	....	1.8	6.0	1.941	..	1.6	3	5	.....	.....	...	...	.....	9		0.3	..	..	....	2.0	5.9	1.946	..

Greenwich mean time for endings of storms: 8^h, Aug. 3; 8^h, Aug. 10; 23^h, Aug. 25; 10^h15^m, Sep. 15; 9^h, Sep. 17 (*this storm

gives the number of hours during which aurora was present. The third column indicates the amount of sky covered by cloud on a scale of 0-10, where 0 means cloudiness, and 10 completely overcast.

Columns four and five describe by letters the form of the aurora, column four indicating forms without ray structure and column five, forms with ray structure. The letters employed are the same as those used in the Photographic Atlas of Auroral Forms published by the International Geodetic and Geophysical Union, Oslo, 1930, so far as it was possible to use those letters. For forms without ray structure *HA* indicates homogeneous quiet arcs; *HB*, homogeneous bands; *PA* pulsating arcs; *DS*, diffuse luminous surfaces; *PS* pulsating surfaces; *G*, feeble glow; *HV*, varied forms; *HF*, flaming aurora, and *HVF*, varied forms with flaming. For forms with ray structure *RA* indicates arcs; *RB*, bands; *D*, draperies; *R*, rays; *C*, corona; *RV*, varied forms; *RF*, flaming aurora; and *RVF*, varied forms with flaming.

Column six gives the maximum area of sky covered in tenths of

cosmic data, August to October, 1931

September								October																	
Aurora								Magnetism				Sun-spot		Solar constant		Aurora									Date
Duration	Cloudiness	Form: with-out rays	Form: with rays	Area covered	Av. altitude	Position	G.M.T. greatest distur.	Char.	Type	G. M. T. begin. distur.		Groups	No.	Value	Char.	Char.	Duration	Cloudiness	Form: with-out rays	Form: with rays	Area covered	Av. altitude	Position	G.M.T. greatest distur	
hrs					°		h			h	m			cal			hrs					°		h	
...	10	.....	.....	...	...	....	...	1	b	6	40	...	...	1.950	f	0	...	5	.....	.....	...	...	....	...	1
...	...	.....	.....	...	...	....	...	1	i	15	....	1	6	1 936	f	1	8	2	HV	RV	0.4	60	NW-NE-E	7	2
...	10	.....	.....	...	...	....	...	1	i	..	....	...	...	1.951	s	...	...	...	.....	.....	...	...	....	...	3
...	10	.....	.....	...	...	....	...	1	b	0	55**	3	3	1.951	s	1	3	6	HA	R	0.2	40	NW-N-NE	13	4
1	9	.....	R	0.2	60	NW-N-NE	11	1	i	..	....	2	3	1.953	s	9	...	10	.....	.....	...	...	....	...	5
5	0	HB	RV	0.6	80	NW-NE-SE	11	1	p	..	....	2	2	.....	..	9	...	10	.....	.....	...	...	....	...	6
...	7	.....	.....	...	...	....	...	0	..	..	....	1	4	.....	..	9	...	10	.....	.....	...	...	....	...	7
...	10	.....	.....	...	...	....	...	0	..	..	....	...	...	.....	..	1	4	7	HV	RB	0.4	25	N-NE-E	13	8
5	7	DS	D	0.4	75	N-NE-E	8	0	..	..	....	...	...	1.936	f	1	2	7	DS	.....	0.2	20	N-NE-A	9	9
5	6	HB	RV	0.6	85	NW-N-E	9	0	..	..	....	1	7	1.947	f	1	2	7	HVF	R	0.2	25	NW-N-NE	14	10
3	9	DS	RV	0.4	30	W-N-NE	11	0	..	..	....	...	...	1.940	f	1	5	7	G	R	0.2	45	NW-N-NE	12	11
4	7	HA	RB	0.4	65	NW-N-NE	10	0	..	..	....	1	1	.....	..	1	2	8	DS	RA	0.2	30	NW-N-NE	10	12
4	9	HV	D	0.4	70	NW-N-NE	10	2	i	5	....	1	3	.....	..	1	1	9	DS	.....	0.2	40	NW......	13	13
...	10	.....	.....	...	...	....	...	0	..	..	....	1	2	1.948	f	2	3	8	DS	RB	0.4	45	NW-N-E	11	14
2	5	HV	RV	0.6	75	W-N-E	6	0	..	..	....	1	2	1.948	s	1	2	9	DS	.....	0.2	30	NW-N-NE	12	15
1	8	HA	RV	0.4	85	NW-N-E	8	0	..	..	....	0	0	.....	..	1	10	9	G	RB	0.2	45	NW-N-E	9	16
4	8	HV	RV	0.9	60	NW-N-E	9	1	i	3	30	...	...	1.936	f	1	3	9	DS	.....	0.2	35	NW-NE-E	9	17
4	8	G	.....	0.2	28	NW-N-NE	9	0	..	..	....	...	...	.....	..	1	3	5	HA	RB	0.6	75	NW-NE-SE	11	18
2	9	DS	.....	0.2	20	N-NE-E	9	1	i	..	....	...	...	.....	..	1	7	2	HA	RB	0.4	50	NW-N-E	11	19
1	9	HA	.....	0.2	30	N-NE-E	6	0	..	..	....	1	1	.....	..	2	7	1	HA	RB	0.4	75	NW-NE-E	12	20
5	8	HB	D	0.4	65	NW-NE-E	12	0	..	..	....	1	2	.....	..	1	9	2	HA	R	0.2	25	NW-N-NE	8	21
1	8	DS	R	0.2	50	NW-N-NE	11	1	p	..	....	1	2	.....	..	9	...	4	.....	.....	...	...	....	...	22
2	9	HB	.....	0.4	90	NW-N-E	8	0	..	..	....	2	10	.....	..	1	2	9	G	.....	0.2	15	NW......	6	23
1	9	HA	.....	0.2	40	N-NE-E	7	0	..	..	....	2	4	.....	..	9	...	10	.....	.....	...	...	....	...	24
...	9	.....	.....	...	...	....	...	0	..	..	....	2	6	.....	..	1	1	0	HA	RB	0.2	20	NW-N-NE	0	25
3	8	HB	.....	0.2	15	N-NE-E	7	0	..	..	....	1	5	.....	..	3	7	1	HV	RV	0.4	50	NW-N-E	9	26
1	0	HB	.....	0.2	10	NW-N-NE	11	0	..	..	....	1	3	.....	..	3	9	3	HV	RV	0.4	60	NW-NE-E	9	27
1	1	HB	.....	0.2	10	NW-N-E	11	1	i	..	....	1	5	.....	..	0	...	7	.....	.....	...	...	....	...	28
3	5	HV	RV	0.6	75	NW-NE-SE	13	1	i	8	40	2	2	.....	..	1	2	9	DS	RB	0.2	45	W-N-E	5	29
...	10	.....	.....	...	...	....	...	2	i	..	....	1	2	.....	..	1	4	9	G	.....	0.4	35	NW-NE-E	12	30
...	...	.....	.....	...	...	....	...	2	o	..	....	1	2	.....	..	1	1	8	G	.....	0.2	25	NW-N-NE	10	31
3	8	.....	.....	...	...	....	9	0.6	..	..	....	1.3	3.3	1.945	..	2.5	4	6	.....	.....	...	...	....	10	Mean

began at 22h, Sep. 16); 8h10m, Oct. 1; 9h, Oct. 3 (**. a second disturbance began at 16h, Oct. 4); 4h, Oct. 6; 9h, Oct. 13.

the whole sky, column seven the average altitude in degrees, and column eight the general position of the aurora, being reckoned for included positions in a clockwise direction with Z representing zenith and A the whole sky. The final column gives the Greenwich mean hour of the observed greatest display in the preceding 24 hours of the Greenwich day.

The data for terrestrial magnetism, sun spots, and solar constant are the same as given in previous tables.

The first three columns of the Table give (1) the magnetic character according to the scale 0-2 of the International Commission of Terrestrial Magnetism and Electricity, (2) the type featuring the day other than normal by the letters *b*, *p*, *o*, and *i* for days marked by bay, rapid pulsations, long-period oscillations, and irregular oscillations, respectively, and (3) the hour and minute of Greenwich mean time marking the beginning of a storm, the end of the storm being indicated in the footnote to the Table. The next two columns give the data relating to sunspots: (1) the number of groups of spots and (2) the total number of spots. It is to be noted that sunspot-numbers such as those from Zürich can be obtained from the number of groups and spots given in the Table by the formula $N=k\ (10g+s)$, where k for Mount Wilson is about 0.77. The sixth and seventh columns show (1) the value in calories of the solar constant, and (2) by letters *s*, *f*, and *u*, whether the determination was satisfactory, fair, or unsatisfactory, respectively.

The table of Kennelly-Heaviside Layer heights is self-explanatory.

Kennelly-Heaviside Layer heights, Washington, D. C.

Date	Frequency	Nearest hour G.M.T.	Height	Date	Frequency	Nearest hour G.M.T.	Height
1931	*kc/sec*	*h*	*km*	1931	*kc/sec*	*h*	*km*
Sept. 8	2,000	19	100	Oct. 6	4,100	15	310
" "	3,000	17	110	" "	3,000	16	120
" "	5,200	18	140, 400	" "	3,650	16	120, 200
" 10	2,000	16	110	" "	3,500	19	240
" "	3,000	17	130, 340	" "	3,000	19	200
" "	5,900	18	90, 660	" "	4,000	20	250
" 16	3,000	21	300	" "	3,250	20	130, 240
" "	4,100	19	170, 350	" "	4,500	21	270
" "	5,000	20	200, 450	" 14	2,500	17	130
" 24	2,000	17	No value obtained	" "	4,100	18	230, 290
" "	2,500	17	120	" "	6,000	19	310
" "	3,000	18	No value obtained	" "	2,000	23	220
" "	3,500	19	150, 230, 330	" "	3,000	24	240
" "	4,100	19	350	" "	4,100	24	360
" "	4,500	19	270, 600	" 20	2,000	17	No value obtained
" "	5,000	20	100, 280, 590	" "	3,000	17	110
" 25	4,100	13	340, 510, 670	" "	4,100	17	330
" 29	3,000	15	120, 330	" 21	1,900	2	310
" "	3,500	17	340	" "	3,000	2	320
" "	2,000	17	290	" 27	3,000	17	110
" "	5,000	18	No value obtained	" "	4,100	20	120
" 30	5,000	7	260	" "	5,000	20	240
" "	6,000	7	280	" 28	1,900	1	120
" "	7,000	8	320	" "	3,000	3	110, 340
" "	8,000	8	No value obtained	" "	5,000	2	210
" "	8,000	8	110, 200				

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ON REMANENT MAGNETISM IN ROCKS

After heating rocks in the magnetic field of the Earth to about 600°C the relative remanent magnetism Q is about 5 to 7. Q is J/KH or the quotient of remanent volume-magnetization J at 20° in field zero by the susceptibility K times magnetic field H which produced the remanence. The remanence is impressed on the rocks during the cooling from 585° C (magnetic critical temperature of magnetite) to about 500° C. By inverting the field in this temperature-interval the magnetization is more or less reversed. At about 480° to 500° the same field, but of opposite sign to that field which has primarily magnetized the rock, gives to the rocks a magnetization equal to zero, when measured at 20° in field zero. Not all zero-magnetizations are equal. A magnetization in a stronger field of 0.4 Γ (oersted) was made equal to zero by heating to about 550° in a weaker field of 0.2 Γ. When heated afterwards in the field zero to 500° the rock shows traces of the former stronger magnetization. Time has a marked influence on the actions of a magnetic field on rocks. Rocks cooled in 15 minutes from 590° to 10° C have only 0.3 to 0.6 of the magnetization which is reached on cooling in the same field in about an hour. But if the rock has remained about an hour at the same temperature and field, a prolongation of the time gives no change larger than 10 per cent, so far as examined. The coercive force is about 30 to 70 Γ for the rocks examined. Strong percussions repeated 10^5 times have changed slightly the magnetization in the first 1000 percussions but not for those following. So far as examined the eruptive rocks older than Perm have a value of Q equal to or less than 2 and generally less than 0.5. For tertiary or younger igneous rocks so far examined, Q is about 2 to 7. Sometimes a value of Q less than 5 is produced in younger effusive rocks by movements in a semiplastic state between 450° and 580°. This was detected by cutting a larger cube into smaller cubes which show different directions of magnetization and which added together give approximately the magnetization of the cube before cutting.

J. G. Koenigsberger

VALEURS MOYENNES ANNUELLES ET MARCHE SÉCULAIRE DES ÉLÉMENTS MAGNÉTIQUES À SWIDER (POLOGNE) POUR L'AN 1930 (LATITUDE 52° 06′.9 N; LONGITUDE 21° 15′.2 E)

Élément	Valeur	Variation séculaire 1930.5—1929.5
D	$-\ 1°57'.3$	$+9'.0$
I	$+67°\ 01'.1$	$+3'.5$
H	18476γ	-31γ
F	47321γ	$+32\gamma$
X	18465γ	-30γ
Y	$-\ 630\gamma$	$+50\gamma$
Z	43565γ	$+48\gamma$

St. Kalinowski

Observatoire Magnétique,
Swider, Pologne, 8 *août* 1931

PRINCIPAL MAGNETIC STORMS

Sitka Magnetic Observatory
April to September, 1931[1]

(Latitude 57° 03′.0 N.; longitude, 135° 20′.1 or 9h 01m.3 W. of Gr.)

Greenwich mean time						Range		
Beginning			Ending			Decl'n	Hor. int.	Ver. int.
1930	h	m	d	h	m	′	γ	γ
May 7	1	..	8	13	..	76.7	874	580
May 14	16	44	15	15	..	58.7	409	355
June 1	15	30	3	07	..	82.0	996*	599
June 8	19	..	9	14	..	63.1	408	359
July 23	3	23	26	15	..	55.6	435	520
Aug. 19	17	..	21	24	..	76.0	463	643
Aug. 24	17	42	25	21	..	36.8	452	506
Sep. 3	5	43	5	14	..	70.2	435	563
Sep. 15	8	..	17	14	..	75.3	378	490

*Curve went off the paper in one direction.

There were no major storms during the quarter April to June.

May 14-15, 1931—The storm of May 14-15 was very small with no particularly active periods, while there were only a few hours of active periods in the other storms.

May 7-8, 1931—The storm of May 7-8 was quite active from $7^d\ 3^h$ to 6^h and from 9^h to 11^h on 7^d, with an abnormally high value of H during the first period.

June 1-3, 1931—The storm of June 1-3 was particularly active from 8^h to 12^h on June 2. During the first part of this period there were some rapid changes in the value of H. At $8^h\ 17^m$ the value was 15501γ, at $8^h\ 41^m$ the value was 14725γ, and at $9^h\ 16^m$ the value was 15706γ.

June 8-9, 1931—The storm of June 8-9 was very small with a moderately active period from 3^h to 7^h on June 8.

There were no large magnetic disturbances during July to September and the above storms in this period might be more properly classified as minor disturbances, with the most disturbed periods as only moderately active.

July 23-26, 1931—This storm has an abrupt beginning and a few hours of moderate activity centering around 13^h, on July 25, 1931.

August 19-21, 1931—The first twelve hours of this storm consisted of small oscillations followed by a period of moderate activity from 5^h to 17^h on August 20.

September 3-5, 1931—The beginning of this storm like the storm of August 24-25 is represented by a small jog in the curves and neither one has a decided abrupt beginning. There is a moderately active period from 2^h to 15^h on September 4 and this period is followed by several disturbed days with small active periods at various times.

September 15-17, 1931—This storm has two active periods, the smaller one with the lesser ranges occurring from 4^h to 10^h on September 16 and the more active one occurring from 3^h to 13^h on September 17.

Franklin P. Ulrich, *Observer-in-Charge*

[1] Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

Cheltenham Magnetic Observatory

April to September, 1931[1]

(Latitude 38° 44′.0 N.; longitude 76° 50′.5 or 5ʰ 07ᵐ.4 W. of Gr.)

There were no magnetic storms recorded during the second and third quarters of 1931.

Geo. Hartnell, *Observer-in-Charge*

Huancayo Magnetic Observatory

April to August, 1931

(Latitude 12° 02′.7 S.; longitude 75° 20′.4 or 5ʰ 01ᵐ W. of Gr.)

There were no magnetic storms recorded during the period.

Paul G. Ledig, *Observer-in-Charge*

Watheroo Magnetic Observatory

April to August, 1931

(Latitude 30° 19′.1 S.; longitude 115° 52′.6 or 7ʰ 43ᵐ.5 E. of Gr.)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Ver. int.
1931	*h* *m*	*d* *h* *m*	′	γ	γ
June 1.......	15 28	2 24 ..	13.7	117	84
July 23.......	3 21	24 1 ..	15.6	84	81

June 1-2, 1931—This disturbance of small to moderate intensity began at 15ʰ 28ᵐ (Greenwich mean time) on June 1. The commencement was not strictly sudden since it extended over a period of 7 minutes. The period of greatest activity was between 9ʰ and 12ʰ on June 2, when the range of H was about 60γ; conditions gradually became quiet by midnight of the same day.

July 23-24, 1931—A disturbance of rather small intensity but marked by some unusual features began at 3ʰ 21ᵐ (Greenwich mean time) on July 23 and lasted until 1ʰ on July 24. The sudden commencement in the H-component was N-shaped, the first upward stroke being almost vertical and corresponding to an increase in H of 5γ. The downward stroke which was completed at 3ʰ 24ᵐ brought the horizontal intensity to its original value. The final upward stroke which was completed at 3ʰ 26ᵐ represented an increase of 11γ. These movements are shown in reduced size in both the D- and the Z-traces. Another feature of the disturbance was the number of small-amplitude, but very short-period impulses imparted to the magnets, the times of the more important of which are given in the following table:

Beginning	Ending	Remarks
h *m*	*h* *m*	
6 11.5	6 13.5	Very rapid oscillations, producing blurred appearance of trace
10 09.0	10 09.5	Very sudden increase of 3γ in H followed immediately by a decrease of 8γ

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

Beginning	Ending	Remarks
10 10.5	10 10.5	Decrease of 3γ and recovery, occupying less than 30 seconds
19 22.0	19 24.0	Double oscillation, shown very clearly on the *D*-trace as *W*-shaped, with the center peak projecting slightly

W. C. Parkinson, *Observer-in-Charge*

APIA OBSERVATORY[1]

A magnetic storm of not violent character was recorded at the Apia Observatory (latitude 13° 48′.4 south, longitude 171° 46′.5 west) on October 29-30, 1931. The commencement was not of the "sudden" type, but developed gradually, the time being $7^h\ 30^m$ G. M. T. on the 29th. The ranges between the extreme maxima and minima were: Declination, 7′.0; horizontal intensity, 79γ. The range in vertical force is not known owing to the vertical-force variometer being out of action.

The *H*-trace fell jerkily by 52γ to a minimum at $11^h\ 30^m$, after which there was a rise to the greatest recorded maximum by 58γ, which was reached at $12^h\ 48^m$. This was followed by a fall of 78γ to a minimum at $15^h\ 34^m$, which was followed by a series of small maxima and minima in which at $6^h\ 12^m$ on the 30th was the extreme minimum, 79γ below the greatest maximum. At $10^h\ 02^m$ on the 30th occurred the second largest maximum, 77γ above the extreme minimum, after which the disturbance gradually died away.

P. W. Glover, *Magnetic Observer*

NOTES

31. *Magnetic observatories in Africa during the Polar Year*—We learn from *Ciel et Terre* (**47**, 188, 1931) that thanks to the efforts of the Colonial Institute and of its President, Professor Dehalu, the participation of Belgium in the scientific work of the Polar Year in the domain of terrestrial magnetism has been decided and is on the way to realization. The Congo equatorial magnetic station requested of Belgium's Geophysical Commission will be installed at Rutchuru (Kivu). The observations will be entrusted to M. Moll, a young doctor of physical and mathematical sciences, who is now preparing for the expedition under Professor Dehalu at the Astronomical Institute at Liége. The recording instruments adopted will be the variometers specially designed by D. la Cour for the Polar Year and Mascart magnetometers, etc.

Reference is made also to a letter from M. Ch. Maurain stating that the Geophysical Institute of Paris has recommended the establishment of a magnetic station in French Equatorial Africa at Bangi. It is to be provided with a Mascart recording apparatus.

32. *New observatory at University of Leipzig*—A large observatory is now being built for the Geophysical Institute of the University of Leipzig. The building, which will be surmounted by an 80-foot tower, is being erected on solid rock in a forest on the Colm at Oschatz, a suburb of Leipzig. Nearby, in a small quarry, an "earthquake cellar" will be excavated for the observatory's seismograph, and two further buildings will be erected for the study of terrestrial magnetism. The main building will be chiefly devoted to the study of atmospheric electricity. All investigations will be carried out along the lines of international geophysical research.

33. *Sitka Observatory*—A magnetograph, which has been completely rebuilt and equipped with temperature-compensation, has been shipped to the Sitka Observatory for installation. New instrument-piers are being installed and there will be a necessary discontinuance of magnetic observations for a limited period while the change of instruments is being effected. However, the improved instruments are expected to give much

[1]Communicated by J. Wadsworth, Director.

more satisfactory results, which is of special importance in connection with the Polar-Year program.

34. *Christchurch Magnetic Observatory*—We learn from the New Zealand press that arrangements had been made in July 1931 to transfer the control of the Magnetic Observatory at Christchurch from the Lands and Survey Department to the Department of Scientific and Industrial Research. Apparently the amalgamation is being effected to bring about closer coordination between the observatories in Wellington, Christchurch, and Apia.

35. *Field-work, United States Coast and Geodetic Survey*—On August 24, 1931, *R. G. Ambrose*, magnetic observer, started on a new program of magnetic observations along the 93rd meridian triangulation. This program involved the selection of first-order triangulation-stations near former repeat-stations, at both of which points complete magnetic observations are being made. Also, declination observations are made at triangulation-stations at intervals of approximately 50 miles along the arc of triangulation being followed. The use of triangulation-stations for magnetic stations has been decided on for two principal reasons. Since these stations are ordinarily out in the open country, they are of a more permanent nature, being less apt to be disturbed by building operations or other construction. Also, the new specifications for first-order triangulation require the setting of an azimuth-mark at a convenient distance from the station-mark. This is for use of government and local surveyors in tying in their surveys with the triangulation-net of that locality. This azimuth also eliminates the necessity for a magnetic observer to determine an azimuth and thus speeds up this work considerably, as his work is then independent of clear weather.

36. *Aeroarctic*—The third general meeting of Aeroarctic was held at Berlin, November 7 to 9, 1931. In addition to the regular business and the reports of the treasurer and general secretary, the following papers were to be presented: The weather conditions before and during the trial flight of the *Graf Zeppelin* and their influence on the course of the Expedition, by L. Weickmann; Results of geographical observations, by R. Samoilowitsch; The magnetic equipment and observational results, by G. S. Ljungdahl; Ice observations, by E. H. Smith and Dr. Kohl-Larsen; The aerological instruments and results of observations, by P. A. Moltchanoff and L. Weickmann; The photometric equipment, methods of work, and discussion of the photogrammetric observational material obtained on the expedition, by O. von Gruber and Cl. Aschenbrenner. The film obtained by the Fox-Hearst Film Company on the trial flight was also to be exhibited.

37. *La Géographie—Terre Air Mer*—In conformity with the modern urge for humanizing the presentation of knowledge, a conspicuous example of which is the fourteenth edition of the Encyclopedia Britannica, several scientific journals have in recent years modified their form so as to appeal to a wider circle of readers. One of the latest journals to follow this tendency is the well-known bulletin of the French Geographical Society, *La Géographie*, which, beginning with September 1931, has been converted into a monthly and now bears the name of *Terre Air Mer* symbolic of its widened future function of not merely reporting discoveries of new lands—since indeed there now remains very little of the globe which is unknown—but the scientific, economic, and descriptive studies of the various countries among which the French colonial possessions will play an important rôle.

Each number of *Terre Air Mer* will contain, besides original articles, sections of "Nouvelles et Correspondance" intended to keep the reader informed of geographical expeditions, meetings, congresses, etc., "Actes de la Société de Géographie" (meetings, lectures, etc.), and finally a chapter "Parmi les livres" in which recent geographical publications will be reviewed. While the altered form of the publication will doubtless exert a greater popular appeal, we shall miss the excellent annotated bibliography which was one of the valuable features of the older publication.

38. *American Institute of Physics*—The recently established American Institute of Physics is an agency for studying the common problems of organizations representing physics in America and for undertaking thereafter such functions as the cooperating societies may assign to it. It will serve the four following societies: American Physical Society, Optical Society of America, Acoustical Society of America, and the Society of Rheology, thus including the majority of American men of science engaged in research work in pure and applied physics. The subjects that the Institute has already been commissioned to study are briefly the problems of publications in physics, their better correlation and adaptation and means of better financial support; the questions of helpful contacts and closer relations among all the organizations and groups, local and extended,

interested in physics; the subject of the relations of physics and physicists with the public, which resolves itself, on the one hand, into interesting and informing the public by use of effective channels of publicity and, on the other hand, into seeking more support for physics from the public. An important function of the Institute will concern the coordination and correlation of work in pure and applied physics with activities in geophysics, astrophysics, and allied sciences. The utility of such a service is obvious and it is expected that existing agencies dedicated to the service of science will find their scope and activities increased through the work of the Institute.

39. *Errata*—In the first line on page 202 of the last number of the JOURNAL, instead of "low sunspot-number (1908)" read "low sunspot-numbers (1911)."

40. *French URSI broadcasts from January 1, 1932*—The scheme of URSIgram broadcast from the French Radiotelegraphic Stations under the auspices of the French Committee on Scientific Radiotelegraphy, effective January 1, 1932, will replace the geophysical bulletins which are at present transmitted by the radiotelegraphic stations of Bordeaux and Pontoise as well as by the radiotelephonic station on the Eiffel Tower. The Eiffel Tower station will continue to send in plain language the geophysical and astrophysical bulletins. In addition to the URSIgram, the Lafayette stations (radiotelegraphic) 18,900-meter waves, and the Pontoise station (radiotelegraphic) 28.50-meter waves, will send out daily a group of letters serving studies on propagation. The program of the various emission will be as follows: $20^h\ 06^m$ (Greenwich), and of the time-signal broadcast; $20^h\ 10^m$ to $20^h\ 15^m$, signals for study of propagation (Emission of the letter *é* ..-.. and a group of control letters); $20^h\ 15^m$, URSIgrams.

The URSIgrams sent out by the Lafayette and Pontoise stations will include: (1) A very condensed meteorological bulletin furnished by the National Meteorological Office—code designation *BAR*. (2) A geophysical bulletin giving information regarding the magnetic and electric states of the Earth furnished by the Institut de Physique du Globe at Paris on the basis of observations made at the Val Joyeux Observatory—code designations *MAG* and *ELC*. (3) An astrophysical bulletin relating to solar activity as shown by observations made at Meudon of sunspots, prominences, filaments, and faculae—code designation *SOL*. (4) A bulletin indicating production centers of atmospherics based on daily observations made at 13^h by the Radio Research Station at Slough, England, to be sent out once a week (generally on Monday) and giving the centers observed the preceding week—code designation *ATS*. (5) A bulletin indicating for a given frequency the height of the Kennelly-Heaviside layer according to the measurements of Prof. Appleton, results being transmitted by the British National Committee—code designation *KHL*.

41. *Personalia*—We regret to record the death October 8, 1931, of Professor *A. Wolfer*, who was for many years the director of the Eidgenössische Sternwarte in Zurich, and who is perhaps most widely known for continuing the important lists of sunspot-numbers, inaugurated by Professor Wolf, which have served as a basis for many important studies of the relations between sunspot-activity and geophysical phenomena.

Dr. *Irwin Roman*, formerly mathematical physicist for the Geophysical Research Corporation, a subsidiary of the Amerada Corporation, and earlier on the staff of Vanderbilt University, has joined the instructional and research staff of the Michigan College of Mining and Technology as assistant professor of mathematics and physics. He will participate in the extensive geophysical research program conducted by the Michigan College of Mining and Technology under the supervision of Professor James Fisher, chairman of Dr. Roman's department.

Dr. *Viktor F. Hess*, professor at the University of Graz, has been appointed professor of experimental physics and director of the Institut fur Strahlenforschung at the University of Innsbruck.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Apia Observatory. Report for 1928 and 1929. Published by the direction of the Honorary Board of Advice, Wellington, N. Z. Wellington, W. A. G. Skinner, Govt. Printer, 1931 (176). 25 cm.

Azores, Service Météorologique. Résumé d'observations de 1928. Lisbonne, Imprimerie Nationale, 1930 (23). 32×24 cm. [Contains annual values of the magnetic elements and monthly mean values of the declination at the S. Miguel Observatory for 1928.]

Bombay and Alibag Observatories. Magnetic, meteorological and seismographic observations made at the Government Observatories, Bombay and Alibag, in the year 1927, under the direction of S. K. Banerji. Calcutta, Govt. India Central Publication Branch, 1931 (iii+132 with 6 pls.). 34 cm.

Coldewey, H. Aeronautische Instrumente bei der Erforschung polarer Gebiete mit Hilfe von Luftschiffen. Arktis, Gotha, Jahrg. 4, Heft 1/2, 1931 (21-25). [Among other instruments, the use of the magnetic compass is briefly discussed.]

Fanselau, G. Messungen mit dem Doppelkompass im Luftschiff, ausgeführt von Haussmann und Nippoldt. Mit einer Vorbemerkung von A. Nippoldt. Arktis, Gotha, Jahrg. 4, Heft 1/2, 1931 (14-18). [An account of the tests of the double compass on a flight of the *Graf Zeppelin* from Friedrichshafen to Mannheim and return on October 18, 1930.]

Hamburg, Deutsche Seewarte. Dreiundfünfzigster Jahresbericht über die Tätigkeit der Deutschen Seewarte für das Jahr 1930. Bearbeitet von der Centralabteilung der Deutschen Seewarte. Hamburg, 1931 (52). 27 cm. [On pp. 15-19 is a report of Abteilung II (Instrumente und Schiffslaternen; Erd- und Schiffsmagnetismus; Technische Navigation).]

Heck, N. H. What is back of the compass-rose. Merchant Marine Bull., Washington, D. C., v. 5, No. 3, 1931 (6-7, 33 with illus.).

Imamiti, S. The report on a testing of Ad. Schmidt's normal-theodolite for use at the Kakioka Magnetic Observatory. Ann. Rep. Kakioka Mag. Obs., 1929, Tokyo, 1931. 20 pp.

International Union of Geodesy and Geophysics. Union Géodésique et Géophysique Internationale. Section de Magnétisme et Electricité Terrestres. Comptes Rendus de l'Assemblée de Stockholm, 15-23 août 1930 publiés par les soins de Ch. Maurain, Secrétaire de la Section et Directeur du Bureau Central. Paris, Les Presses Unversitaires de France, 1931 (x+479). 25 cm. [This publication, reviewed in this number of the Journal, is Bulletin No. 8 of the series issued by the Section of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics and contains the detailed transactions of the meetings of the Section held at Stockholm in August 1930. Its contents are grouped under the following headings: (1) Généralités et procès verbaux; (2) Rapports des comités nationaux; (3) Rapports sur des sujets spéciaux comme suite à des décisions prises à l'Assemblée de Prague; (4) Communications sur différents sujets; (5) Questions traitées en commun avec d'autres sections; (6) Résolutions et voeux.]

Kohl, E. Ueber die Ermittlung tektonischer Linien mittels der magnetischen Feldwaage in Gebieten geringer Unterschiede der magnetischen Vertikalintensität, im besonderen in Norddeutschland. Kali, Berlin, Bd. 25, 1931 (209-215, 225-230, 241- 243).

Lagrange, E. La variation diurne des éléments et le mystère magnétique. Ciel et Terre, Bruxelles, 47e année, 1931 (173-176).

London, Meteorological Office. The observatories' year book 1929 comprising the meteorological and geophysical results obtained from autographic records and eye observations at the observatories at Lerwick, Aberdeen, Eskdalemuir, Cahirciveen (Valentia Observatory), Richmond (Kew Observatory), and results of soundings of the upper atmosphere by means of registering balloons. London, H. M. Stationery Office, 1931, 441 pp. 31 cm.

Annual report of the Director of the Meteorological Office presented by the Meteorological Committee to the Air Council for the year ended March 31, 1931. London, H. M. Stationery Office, 1931 (53). 24 cm. [Contains brief reports on Kew, Eskdalemuir, Aberdeen, Lerwick, and Valentia observatories.]

Melbourne Observatory. Mean hourly values of the magnetic elements at Toolangi, 1928 and 1929. Observed and reduced under the direction of J. M. Baldwin. Melbourne, H. J. Green, Govt. Printer [1931] (iv+7). 24 cm. [In explanation of the reduced size of the publication, the following statement in the introduction is quoted: "Owing to the need of exercising the strictest economy the previous practice of publishing the complete list of hourly values has been departed from, and it has been decided to give the monthly means for each hour for each of the three recorded elements. The means for each hour of the five international quiet days and of the ten least disturbed days of each month are also given. If the separate hourly values are required for any special research, they will be supplied on loan in manuscript on application from any worker wishing to make use of them."]

Mount Wilson Observatory. Summary of Mount Wilson magnetic observations of sunspots for May and June 1931. Pub. Astr. Soc. Pacific, San Francisco, Cal., v. 43, 1931 (308-309).

Nippoldt, A. Die magnetischen Variationen in Seddin während des Nordlichts am 14 November 1930. Met. Zs., Braunschweig, Bd. 45, Heft 7, 1931 (266-267).

Raymond, G. Sur la variation diurne de la boussole de déclinaison à Antibes, de 1911 à 1930. Paris, Bul. Soc. Astr. France, 45° annee, juillet, 1931 (314-315). [Contains table giving the diurnal variation of the magnetic declination for the months January 1911 to December 1930 at Antibes, Alpes-Maritimes, France.]

Reich, H. Eigenschaften der Gesteine. Handbuch der Geophysik, Bd. 6, 1931 (1-83). [Herausgegeben von B. Gutenberg. Berlin, Gebrüder Borntraeger. Chapters 4 and 5 deal with the electrical conductivity and the magnetic properties of rocks, respectively.]

San Fernando. Anales del Instituto y Observatorio de Marina, publicados de orden de la Superioridad. Sección 1. Observaciones meteorológicas, magnéticas y sísmicas. Año 1930. San Fernando, 1931 (iii+89). 34 cm.

Sodankylä. Ergebnisse der Beobachtungen des Magnetischen Observatoriums zu Sodankylä im Jahre 1920. Von E. R. Levanto. (Veröff. Mag. Observatoriums der Finnischen Akad. Wiss., Nr. 7.) Kuopio, Osakeyhtiö Kirjapaino Sanan Valta, 1931 (55 mit 4 Tafeln). 29 cm.

Ergebnisse der Beobachtungen des Magnetischen Observatoriums zu Sodankylä im Jahre 1927. Von E. Sucksdorff. (Veröff. Mag. Observatoriums der Finnischen Akad. Wiss., Nr. 14.) Kuopio, Osakeyhtiö Kirjapaino Sanan Valta, 1931 (55 mit 4 Tafeln). 29 cm.

Tokyo, Central Meteorological Observatory. The annual report of the Kakioka Magnetic Observatory, Japan, for the year 1929. Tokyo, 1931 (39 with 16 pls.). 30 cm. [Contains besides results of the magnetic observations, the magnetic variability observed at Kakioka Magnetic Observatory, Japan, for 1929, as well as "The report on a testing of Ad. Schmidt's normal theodolite for the use of the Kakioka Magnetic Observatory" by S. Imamiti.]

B—Terrestrial and Cosmical Electricity

Austin, A. O. Lightning investigation as applied to the airplane. Washington, D. C., Mon. Weath. Rev., v. 59, No. 7, 1931 (259-264).

B., A. La protection des lignes électriques contre la foudre. Nature, Paris, No. 2862, 1er août 1931 (104-106).

BAECHLE, J. W. Shooting lightning. Pop. Astr., Northfield, Minn., v. 39, No. 7, 1931 (365-366). [The author describes the difficulty encountered in focusing the lightning on the ground glass of the camera in the darkness. This obstacle was overcome by focusing on a flash-light at a distance of about 100 feet.]

BARNÓTHY, J., UND M. FORRÓ. Das Wesen der Ultrastrahlung. Zs. Physik, Berlin, Bd. 71, Heft 11/12, 1931 (778-791). [Zwecks Bestimmung der Natur der Ultrastrahlung wird ihre Intensitätsverteilung in den Richtungen senkrecht zum magnetischen Meridian von 50° (Westen) bis 140° (Osten) bestimmt. Es wird ein Maximum der Intensität bei 90° und bei 120° gefunden.]

BECKETT, H. E., AND A. F. DUFTON. Unusual lightning. Nature, London, v. 128, Aug. 1, 1931 (189). [Brief note regarding a display of unusual lightning observed from 10.15 p. m. to 11.30 p. m. on July 12, 1931, at Garston, Herts., England.] Comments on the above by C. J. P. Cave, Nature, London, v. 128, Aug. 29, 1931 (378).

BRAAK, C. Onweer in de tropen. Hemel en Dampkring, Groningen, v. 28, 1930 (248-251). [Thunder-storms in the tropics.]

CHAPMAN, S. The absorption and dissociative or ionizing effect of monochromatic radiation in an atmosphere on a rotating earth. Part II. Grazing incidence. London, Proc. Phys. Soc., v. 43, Pt. 5, 1931 (483-501).

CORLIN, A., UND V. F. HESS. Beitrag zur Kenntnis der Solarkomponente der kosmischen Ultrastrahlung. Beitr. Geophysik, Leipzig, Bd. 31, Heft 1/3, 1931 (169-172).

DAUVILLIER, A. Aurores polaires et rayons cosmiques. Paris, C.-R. Acad. sci., T. 193, No. 7, 1931 (348-350).

DORCHESTER, C. S., AND L. W. BUTLER. On atmospheric electricity. Science, New York, N. Y., N. S., v. 74, No. 1910, 1931 (155-157). [Description of experiment to study the effect of atmospheric electricity on the growth of plants].

DOUGLAS, C. M. K. Thunder-storms, August 3rd to 5th. Met. Mag., London, v. 66, No. 787, 1931 (158-159). [Description of meteorological conditions during August 3 to 5, 1931, when thunder-storms occurred generally over England.]

High-level thunder-storms in Switzerland. Met. Mag., London v. 66, No. 787, 1931 (168-169).

EREDIA, A. La frequenza delle scariche atmosferiche in Italia nel quadriennio 1925-1928. Meteor. prat., Subiaco, anno 11, No. 4, 1930 (187-191).

FORD, C. B. The height of the auroral band of June 8, 1931. Pop. Astr., Northfield, Minn., v. 39, No. 7, 1931 (428-429). [The height found for the aurora of June 8, 1931 was 301.38 miles whereas that for the display of September 18, 1930, was 196.414 miles, both figures being abnormally high as compared with those obtained in Norway and Canada by photographic means.]

GILL, S., AND W. F. ROGERS. Relation of long-line currents to soil-corrosion. Physics, Menasha, Wis., v. 1, No. 3, 1931 (194-204). [This paper describes an investigation to determine the possible influence on corrosion of so-called "long-line currents" which, unlike "stray currents" occur at long distances from any possible external source of electric current and are supposed to originate between the soil and the pipe. Measurements were made on an 8-inch oil-line upon which much corrosion difficulty had been experienced. From the data obtained the following conclusions were drawn: (1) Discharge or accumulation of electric currents of the class termed "long-line currents" is, in general, without influence upon corrosion of buried pipe-lines; (2) Electrical resistivity of soil correlates to a certain extent with corrosion of buried pipe; the relation is not sufficiently consistent to be of practical value; (3) There is no consistent relationship between soil-resistivity and the accumulation or discharge of "long-line currents."]

HALLIDAY, E. C. The electrical field in the atmosphere. S. Afric. J. Sci., Cape Town, v. 27, 1930 (158-162).

HARANG, L. Ueber das Auftreten eines besonderen Nordlichtbogens am 26 Januar 1931. Zs. Geophysik, Braunschweig, Jahrg. 8, Heft 5/6, 1931 (271-274). [Es wird über einen Nordlichtbogen berichtet, welcher anähernd senkrecht auf die gewöhnliche Bogenrichtung lag.]

HESS, V. F., UND W. S. PFORTE. Ueber die solare Komponente der Ultrastrahlung. Zs. Physik, Berlin, Bd. 71, Heft 3/4, 1931 (171-178). [New measurements of the hard ultraradiation using a Hoffmann twin high-pressure apparatus furnish a further strong argument for the existence of a solar component of the ultraradiation. The daily course of the ionization shows—with shielding of 10 cm thickness of lead—a distinct maximum about noon (local time). The maximal share of the solar component in the total radiation amounts to about 5 per cent. From the daily curve the absorption-coefficient of the solar component could be determined as about $\mu = 5 \times 10^{-4}$ cm^{-1} (H_20). On the basis of this value the seasonal and geographic dependence of the solar component of the ultraradiation was computed.]

HUMMEL, J. N. Die Tiefenwirkung der Potentiallinien- und Rahmenmethoden bei geschichtetem Untergrund. Zs. Geophysik, Braunschweig, Jahrg. 8, Heft 5/6, 1931 (258-265). [Der Untergrund bestehe aus zwei horizontalen Schichten, deren untere einen Störungskörper aufnimmt. Es wird der Einfluss der Deckschicht auf das Potentiallinienbild an der Erdoberfläche untersucht. Die Störungsgrösse wird mit der des entsprechenden elektromagnetischen Feldes verglichen.]

HUNKEL, H. Die elektrischen Aufschlussmethoden. Handbuch der Geophysik, Bd. 6, 1931 (84-165). [Herausgegeben von B. Gutenberg. Berlin, Gebrüder Borntraeger.]

ISRAËL, H. Zur Theorie und Methodik der Grössenbestimmung von Luftionen. Beitr. Geophysik, Leipzig, Bd. 31, Heft 1/3, 1931 (173-216).

JENSEN, CHR. Kurzer Ueberblick über Professor Carl Störmers Arbeiten. Ann. Hydrogr., Berlin, Jahrg. 59, Heft 7, 1931 (267-270).

KAPLAN, J. The auroral spectrum. Abstract: Phys. Rev., Menasha, Wis., v. 38, No. 3, 1931 (582).

Excitation of the green auroral line. Nature, London, v. 128, Aug. 22, 1931 (304).

LEWIS, W. W., AND C. M. FOUST. Direct strokes to transmission-lines. Gen. Elec. Rev., Schenectady, N. Y., v. 34, No. 8, 1931 (452-458). [Consideration of lightning as a disturbing factor in transmission and distribution of electrical power and of certain protective measures for reducing the number of these disturbances.]

MACKY, W. A. Some investigations on the deformation and breaking of water drops in strong electric fields. London, Proc. R. Soc., A, v. 133, 1931 (565-587 with 5 pls.).

MATHIAS, E., ET G. GRENET. Le champ électrique au sommet du Puy de Dôme. Paris, C.-R. Acad. sci., T. 193, No. 13, 1931 (470-473).

MILLIKAN, R. A., AND I. S. BOWEN. Similarity between cosmic rays and gamma-rays. Nature, London, v. 128, Oct. 3, 1931 (582-583).

MOTHES, H. Gleichzeitige Registrierung von Potentialgefälle, Raum- und Oberflächenladung. Göttingen, Nachr. Ges. Wiss., Math.-Phys. Kl., Heft 1, 1931 (49-59).

NOLAN, J. J., AND P. J. NOLAN. Observations on atmospheric ionization at Glencree, Co. Wicklow. Dublin, Proc. R. Irish Acad., A, v. 40, No. 2, 1931 (11-59).

PERNICE, E. Das Gewitter am 26. April 1930 nachmittags zu Berlin. Met. Zs., Braunschweig, Bd. 48, Heft 9, 1931 (329-334).

PERSICO, E. I raggi cosmici. Scientia, Milano, v. 49, 1931 (81-94). [General account of the penetrating-radiation with special reference to cosmic rays for which the author discusses the theories advanced respecting their origin. He discusses particularly the one according to which the cosmic rays are regarded as ether (ultra-γ) vibrations until they reach the limit of the Earth's atmosphere. While traversing the Earth's atmosphere they capture electrons from the molecules of air and arrive at the Earth's surface accompanied by very swift (ultra-β) corpuscles. Then follows the examination of the probable causes likely to give rise to the primary radiation with respect to the hypothetical phenomenon of the destruction of matter and the synthesis of the elements.]

POTTER, E. V. Results of electrical resistivity and electrical induction measurements at Abana Mine, Quebec, Canada. With explanation of some factors associated with induction-method. Washington, D. C., U. S. Dept. Comm., Bur. Mines, Tech. Paper 501, 1931 (28 with 22 figs.). 23 cm.

RAYLEIGH (LORD). Absolute intensity of the aurora line in the night sky, and the number of atomic transitions required to maintain it. London, Proc. R. Soc., A, v. 129, 1930 (458-467).

RIZZO, G. B. Piccoli e grossi corpuscoli elettrizzati (ioni) nell' aria. Universo, Firenze, Anno. 12, Num. 8, 1931 (123-128).

ROSSI, B. Magnetic experiments on the cosmic rays. Nature, London, v. 128, Aug. 22, 1931 (300-301).

Measurements on the absorption of the penetrating corpuscular rays coming from inclined directions. Nature, London, v. 128, Sept. 5, 1931 (408).

Sull' origine della radiazione penetrante corpuscolare dell' atmosfera. Nuovo Cimento, Pisa, v. 8, 1931 (49-70).

Ricerche sull' azione del campo magnetico terrestre sopra i corpuscoli della radiazione penetrante. Nuovo Cimento, Pisa, N. S., v. 8, 1931 (87-97). Abstract: Zentralbl. Math., Berlin, Bd. 1, Heft 6, 1931 (381-382).

SCHERHAG, R. Die Entstehung der Ostgewitter. Met. Zs., Braunschweig, Bd. 48, Heft 7, 1931 (245-254). [Summary of the author's Dissertation: Ueber die atmosphärischen Zustände bei Gewittern. Berlin, 1931.]

SCHWARZ, L. Nordlicht am 14. November 1930 auf der Schneekoppe beobachtet. Met. Zs., Braunschweig, Bd. 45, Heft 7, 1931 (264-266).

STADE, H. Nordlichtbeobachtungen im November 1930. Met. Zs., Braunschweig, Bd. 45, Heft 7, 1931 (268).

STEINMAURER, R. Zur täglichen Periode der Ultrastrahlung. Met. Zs., Braunschweig, Bd. 45, Heft 7, 1931 (270-271).

STÖRMER, C. Ein Fundamentalproblem der Bewegung einer elektrisch geladenen Korpuskel im kosmischen Raum. Zweiter Teil. Zs. Astroph., Berlin, Bd. 3, Heft 3, 1931 (227-252). [Es wird in diesem zweiten Teil eine Untersuchung der Bahnkurven ins unendlich Ferne gemacht auf Grund gewisser Reihenentwicklungen nach fallenden Potenzen der Bogenlänge. Die Konvergenz dieser Reihenentwicklungen wird nachgewiesen, und die ersten Glieder der Reihen für die Koordinaten des Korpuskels werden gefunden. Hieraus ergeben sich einfache physikalische und geometrische Interpretationen de Konstanten a_2, a_4 und c_2.]

SVERDRUP, H. U. Audibility of the aurora polaris. Nature, London, v. 128, Sept. 12, 1931 (457).

THOST, E. Ein Kugelblitz. Met. Zs., Braunschweig, Bd. 48, Heft 7, 1931 (269-270). [Detailed description of an interesting case of ball-lightning observed near Erfurt, Germany, on April 20, 1931.]

TUWIM, L. Zur Berechnung der Zählrohreffekte der Höhenstrahlung und ihrer Absorptionsgesetze bei Messungen mit einem Zählrohr. Berlin, SitzBer. Ak. Wiss., No. 19, 1931 (360-373).

WÖLCKEN, K. Messungen der Ultrastrahlung (durchdringende Höhenstrahlung) zwischen 57 und 67° nördl. Breite. (Vorläufige Mitteilung). Zs. Geophysik, Braunschweig, Jahrg. 8, Heft 5/6, 1931 (267-271). [The penetrating-radiation was measured with a Kolhörster ionization-chamber during a sea trip from Denmark to Greenland. Tables containing the observed values are given. On account of the small degree of precision attained, it was impossible to recognize a maximum of the radiation between latitude 55° and 60° north, or any other dependence on geographic or magnetic latitude.]

C—Miscellaneous

ADAMS, L. H., AND J. W. GREEN. The influence of hydrostatic pressure on the critical temperature of magnetization for iron and other materials. Phil. Mag., London, v. 12, No. 76, 1931 (361-380).

BUSER, FR. Altes und Neues über Zodiakallichtforschung. Weltall, Berlin, Jahrg. 30, Heft 9, 1931 (125-128).

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Dobson, G. M. B. Ozone in the upper atmosphere and it relation to meteorology. London, Proc. R. Inst., v. 26, No. 125, 1931 (373-383).

Edge, A. B. B., and T. H. Laby (Editors). The principles and practice of geophysical prospecting being the report of the Imperial Geophysical Experimental Survey. Cambridge University Press, 1931 (viii+372 with 1 pl. and 261 figs.). 29 cm. [The work recorded in this volume was carried out under the joint auspices of the British Empire Marketing Board and the Commonwealth Government for the purpose of testing the applicability of various geophysical methods under field conditions in Australia which, it was thought, might be fairly characteristic of considerable portions of the British Empire. Electric, gravimetric, magnetic, and, to a limited extent, seismic methods were examined in country containing sulphide and other ores, brown coal, graphite, etc. Full descriptions of the instruments and field procedure employed are given and accounts of the principles upon which the several geophysical methods are based, have been included.]

Fleming, J. A. The Jubilee International Polar Year. Sci. Mon., New York, N. Y., v. 33, No. 4, 1931 (375-380).

Götz, F. W. P. Zum Strahlungsklima des Spitzbergensommers. Strahlungs- und Ozonmessungen in der Königsbucht 1929. Beitr. Geophysik, Leipzig, Bd. 31, Heft 1/3, 1931 (119-154).

Harteck, P. Die Schwankungen des Ozongehaltes der Atmosphäre. Naturw., Berlin, Jahrg. 19, Heft 42, 1931 (858-860).

Heck, N. H. Coming to grips with the earthquake problem. Philadelphia, Pa., J. Frank. Inst., v. 212, No. 3, 1931 (269-303).

International Union of Geodesy and Geophysics. Quatrième assemblée génerale réunie à Stockholm, 15-23 août 1930. Toulouse, Imprimerie et Librairie Edouard Privat, 1931, 99 pp. 25 cm. [Procès-verbaux des séances suivis de trois appendices (1) Pays affiliés à l'Union géodésique et géophysique internationale, avec liste des Organismes adhérents (août 1930); (2) Liste des délégués et des invités à l'Assemblée générale de Stockholm; (3) Composition des Bureaux de l'Union, des Associations et des Comités nationaux de Géodésie et Géophysique.]

Messerschmidt, W. Eine neue Methode zur Bestimmung des Emanationsgehaltes der Atmosphäre. Physik. Zs., Leipzig, Jahrg. 32, Nr. 14, 1931 (548-549).

Müller, F. Beiträge zur Methode der Radioaktivitätsuntersuchungen in der angewandten Geophysik. Zs. Geophys., Braunschweig, Jahrg. 7, Heft 5/6, 1931 (241-247). [Eine Reihe von Versuchsbedingungen, welche bei Radioaktivitätsuntersuchungen wesentlich zu beachten sind, wird besprochen, neue methodische Massnahmen werden beschrieben, und der Anwendungsbereich dieser Untersuchungen als geophysikalisches Aufschlussverfahren näher begrenzt.]

Müller, M. Eine Apparatur zur Erzeugung und Messung niederfrequenter elektromagnetischer Wechselfelder. Zs. Geophysik, Braunschweig, Jahrg. 7, Heft 5/6, 1931 (248-258).

Picht, J. Ueber die Anordnung der Optik bei Lichtschreiber-Registrierapparaten. Zs. Geophysik, Braunschweig, Jahrg. 7, Heft 5/6, 1931 (265-266). [Es wird eine Vorschrift für die gegenseitige Stellung von Galvanometerlinse, Zylinderlinse und photographisches Papier bei Registrierapparaten gegeben.]

Pahlen, E. v. d., und A. Kohlschütter. Untersuchungen über die Sonnenkorona. Zs. Geophysik, Braunschweig, Jahrg. 8, Heft 5/6, 1931 (275-293). [Several theories which have been advanced for explaining the form of the coronal streamers are discussed and tested with the aid of photographs obtained during the solar eclipse of September 10, 1923. The "magnetic" theory of C. Störmer was found to explain best the observed forms and in connection with some other observational data, permitted computing the intensity of the magnetic field of the Sun within the space embraced by the outer corona. A very small value was obtained for this intensity from which it is inferred that there must be a very considerable shielding of the Sun's magnetic field by the ionized solar atmosphere.]

Plendl, H. Ueber den Einfluss der elfjährigen Sonnentätigkeitsperiode auf die Ausbreitung der Wellen in der drahtlosen Telegraphie. Zs. Hochfrequenztech, Leipzig, Bd. 38, Heft 3, 1931 (89-97).

PRIEBSCH, J. Zur Verteilung radioaktiver Stoffe in der freien Luft. Physik. Zs., Leipzig, Jahrg. 32, No. 16, 1931 (622-629).

SCHAFER, J. P., AND W. M. GOODALL. Radio transmission studies of the upper atmosphere. New York, N. Y., Proc. Inst. Radio Eng., v. 19, No. 8, 1931 (1434-1445). [In this paper are given a number of measurements showing time-variations in the virtual height of the ionized regions of the upper atmosphere. Points of main interest are: (1) The data indicate the existence of two distinct ionized regions or layers. The changes in virtual height are sometimes very abrupt. The existence of the lower layer even at night is indicated by an occasional return to low virtual heights during this period. (2) Experimental evidence has been found of large retardations in group-velocity near the critical conditions for which the waves just penetrate the layer to the point of maximum ionization. (3) Except at these critical periods the records for simultaneous transmissions show that the virtual heights of the upper layer are greater for the higher than for the lower frequency. (4) In the discussion several possible methods of two-layer formation are suggested, one of which involves the formation of negative ions in the region between the layers.]

SCHOLZ, J. Ein neuer Apparat zur Bestimmung der Zahl der geladenen und ungeladenen Kerne. Zs. Instrumentenk., Berlin, Jahrg. 51, Heft 10, 1931 (505-522).

SHAW, H., J. McG. BRUCKSHAW, AND S. T. NEWING. Applied geophysics. A brief survey of the development of apparatus and methods employed in the investigation of subterranean structural conditions and the location of mineral deposits. London, H. M. Stationery Office, 1931 (101 with 10 pls.). 24 cm. Price 2s. net. [Issued by the Board of Education, Science Museum. The first half of the pamphlet is devoted to an account of the development of geophysical prospecting and a brief description of the various methods of applied geophysics. The latter half contains a descriptive list of the apparatus on exhibit at the Science Museum illustrating the development of the science.]

TOUCHET, E. La photographie en couleurs du "rayon vert." Nature, Paris, No. 2862, ler août 1931 (100-104).

VREELAND, F. K. Discussion on Kennelly-Heaviside layer height observations for 4045 kc and 8650 kc. New York, N. Y., Proc. Inst. Radio Eng., v. 19, No. 8, 1931 (1499-1505). [The paper under discussion was written by T. R. Gilliland, and appeared in Proc. Inst. Radio Eng., v. 19, No. 1, 1931 (114-119).]

WANTLAND, D. A discussion of the relationship between geology and geophysics. Colo. School Min. Mag., Golden, Colo., v. 21, No. 10, 1931 (31-32, 43, 45).

WHITE, E. L. C. A method of continuous observation of the equivalent height of the Kennelly-Heaviside layer. Cambridge, Proc. Phil. Soc., v. 27, Pt. 3, 1931 (445-450 with 1 pl.). [Summary: A development of the "echo" method of observation of the height of the Kennelly-Heaviside layer is described. Short wave-trains of radiation lasting 1/4000 sec. are transmitted at regular 1/200 sec. intervals, and observed stroboscopically, together with their echoes, by means of a cathode-ray oscillograph. Details of the transmitting and receiving apparatus are given The rapid fluctuation in amplitude of the echoes is easily studied by this method.]

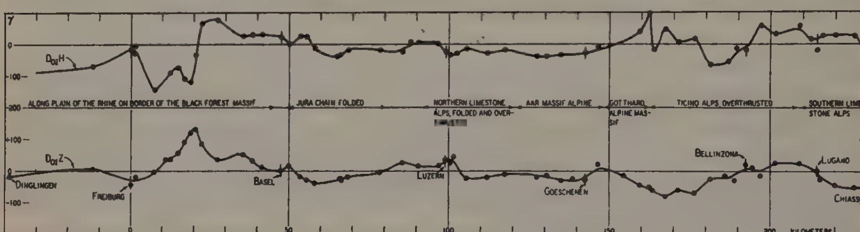
NOTICE

(See also page 356)

ADDITIONAL NOTES ON OBSERVATIONS OF MAGNETIC ANOMALIES WITH A VARIOMETER

Referring to my article in the preceding number of this JOURNAL (pp. 243-249), I have pleasure in sending herewith a graph with another abscissæ-axis to take the place of Figure 5; this now is a projection on a north-south line and shows further and improved analysis as regards part of the line of the magnetic profile through the Black Forest, the Swiss Jura, and the Swiss Alps, including the additional observations obtained (and summarized in Table 1 of the previous communication) to extend it to Lago di Lugano and Chiasso in Italy.

The curvatures of the profiles for the differences of H and Z against the normal values as shown in the Figure herewith indicate the depth



of the center of the disturbing rock on the first 25 km of the line to be about 7 to 12 km between kilometers 15 and 20 for the principal anomaly, and that of a second anomaly to be about 5 km in the same region between kilometers 15 and 20—more probably caused by intrusive basic rocks than tectonics. The same or similar anomaly was detected on the other side of the Rhine (Alsatia, France) by J. Jung and C. Alexanian [Ann. Office Nation. Combustibles Liquides, **6**, 43-58 (1931)]. Anomalies having depths of centers about 5 km are indicated at kilometer 100 and at kilometer 150, and another center of depth more than 10 km at kilometer 200, as well as indications of some weak and shallow maxima at kilometers 163 and 190. Shallow minima (values under zero) for vertical intensity appear to extend from kilometers 120 to 180 and from kilometer 215 farther south. It is possible, however, that the normal gradient of the whole region Freiburg to Chiasso was taken a little too high for Z, namely, 600 gammas per 100 km, and that instead of two minima there are really two less shallow maxima extending from kilometers 140 to 160 and from kilometers 170 to 240. Smaller anomalies are not easily detected in case their effects are not far-reaching.

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DATE DUE
